LITANI WATER QUALITY MANAGEMENT PROJECT

TECHNICAL SURVEY REPORT
SUMMER CONDITIONS

AUGUST 2005

LITANI BASIN MANAGEMENT ADVISORY SERVICES (BAMAS)

BUREAU FOR ASIA AND THE NEAR EAST

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT

REPORT PREPARATION

This report was prepared by *Development Alternatives, Inc.* (DAI), 7250 Woodmont Avenue, Bethesda MD 20814 USA (under contract with the United States Agency for International Development, Contract Number LAG-I-00-99-00017-00, the Integrated Water and Coastal Resources Management (WATER IQC) Task Order No. 818) in collaboration with *Water and Environment Sustainable Solutions s.a.r.l.* (WESS) and *Khatib and Alami Consolidated Engineering Company s.a.l.*, Beirut, Lebanon.

EXECUTIVE SUMMARY

Following the recommendations of the *Winter Technical Survey*, which was completed in May 2005, as part of Task 2 of the Litani BAMAS Project, a summer environmental sampling and analysis campaign was conducted to assess the pollution situation in the Upper Litani Basin during the dry season. Accordingly, site reconnaissance visits were conducted during June-July 2005 to ascertain observations of the field winter reconnaissance completed during February 2005 and document changes since that time. As discerned in the winter survey, the sources vary between domestic wastewater discharge, industrial effluent, and solid waste landfill/disposal sites. Again, it was observed that wastewater/industrial effluents are still being directly discharged into the Litani river and its tributaries without prior treatment. Yet, during the summer season, the flow of the water in the Litani river was considerably low, due to low water flow from spring sources and direct water pumping via pumps installed at the river bank, water diversion through earthern canals for irrigation, and/or intentional blocking of the natural river flow for water collection purposes. These factors and practices are resulting in a minimum quantity of water reaching the Qaraoun Lake, unlike during the winter season.

The summer sampling program comprised of the collection of water samples from the Litani River and its tributaries, groundwater samples throughout the basin, water samples from Canal 900, water and fish samples from the Qaraoun lake, and soil and crop samples from irrigation areas adjacent to Canal 900. To the extent feasible, samples were collected from the same locations selected during the winter sampling program. The collected samples were analyzed for a pre-defined set of bacteriological, physical, and chemical parameters and the results were compared with international and national standards for different water uses. Table I presents the number of collected samples and the corresponding type of analysis.

The main results of the sampling campaign are as follows:

- Several chemical and biological indicators show that water samples from the Litani River and its tributaries exhibited concentrations exceeding drinking, bathing, domestic, and irrigation water quality standards at the dry summer season.
- Field observations and water quality analysis indicate that the most significant sources of contamination to surface and groundwater are associated with the uncontrolled discharge of untreated wastewater along the Litani River and its tributaries highlighting the need for investing in wastewater treatment plants.
- The highest levels of contamination along the river fall within the mid-upper Litani basin where the largest communities are located and are discharging into the river.
- Due to low dilution in the summer season, the microbiological levels in the water samples collected from the Litani river and tributaries more than double in more than 60 percent of the samples, as compared to the winter survey results.
- The quality of the water in Qaraoun Lake and in Canal 900 was found to be acceptable for irrigation under certain restrictions.

Table I. Type of analysis conducted on the various samples collected

Matrix	*Analysis type*	
	Type I- Full Analysis	*Type II- Partial Analysis*
River water Lake water Canal water Industrial wastewater Domestic wastewater	▪ Total coliform ▪ Fecal coliform ▪ Nitrates ▪ Phosphates ▪ Sulfates ▪ Ammonia ▪ Total dissolved solid ▪ BOD ▪ COD ▪ Lead ▪ Cadmium ▪ Chromium	▪ Total coliform ▪ Fecal coliform ▪ Nitrates ▪ Phosphates ▪ Sulfates ▪ Ammonia ▪ Total dissolved solid ▪ BOD ▪ COD
No. of samples	*20*	*134*
Groundwater	▪ Total coliform ▪ Fecal coliform ▪ Nitrates ▪ Phosphates ▪ Sulfates ▪ Nickel ▪ Copper ▪ Zinc ▪ Lead ▪ Cadmium ▪ Chromium ▪ Organochlorines ▪ Organophosphorous	▪ Total coliform ▪ Fecal coliform ▪ Nitrates ▪ Phosphates ▪ Sulfates
No. of samples	*10*	*50*
Soil	▪ Copper ▪ Cadmium ▪ Chromium	
No. of samples	*30*	
Fish tissue	▪ Copper ▪ Cadmium ▪ Chromium	
No. of samples	*9*	
Crop	▪ Copper ▪ Cadmium ▪ Chromium	
No. of samples	*15*	

- The levels of physico-chemical and microbiological parameters in the Qaraoun Lake waters dropped in the summer as compared to the winter survey, mainly due to the fact that the levels of pollutants in the Lake during summer are governed mostly by Lake dynamics (dilution, stratification, currents, sedimentation), particularly that the river-lake system is interrupted by the low flow of contaminant-laden water into the Lake.
- An increase of levels of nitrates in groundwater samples during the summer ascertained the impact of current agricultural practices on groundwater quality and the importance of extension programs to insure proper application of fertilizers.

- High total and fecal coliform levels can be attributed to wastewater discharge practices in the area, including non-maintained septic tanks and open discharges.
- Additional sampling and analysis are recommended to assess heavy metal levels in the soil and fish.

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LIST OF ABBREVIATIONS

AUB	American University of Beirut
AREC	The American University of Beirut’s Agricultural, Research and Education Center
BAMAS	Basin Management Advisory Services
ECL	Environmental Core Laboratory at AUB
EERC	Environmental Engineering Research Center at AUB
GPS	Global Positioning System
DAI	Development Alternatives Inc.
MoE	Ministry of Environment
NPS	Non-point Source
UNDP	United Nations Development Program
USAID	United States Agency for International Development
USEPA	United States Environmental Protection Agency
WESS	Water and Environment Sustainable Solutions s.a.r.l.
WHO	World Health Organization

1. FIELD SUMMER RECONNAISSANCE

Following the winter survey, a second site reconnaissance survey was carried out in an attempt to charatcterize the summer conditions of the upper Litani basin before initiating the summer sampling program. Accordingly, site visits were conducted during June-July 2005 to ascertain observations of the field winter reconnaissance completed during February 2005 and document changes since that time (USAID, 2005b), with particular emphasis on the current condition of the water sources, flow paths, confluences, and sources of environmental stress, namely domestic and/or industrial wastewater discharge. In addition, accessibility to sampling locations was verified during these visits. Field observations coupled with photographic documentation were systematically recorded on a field log book, a sample of which is presented in Appendix A, with corresponding location description, coordinates using a Global Positioning System (GPS), and other relevant information.

1.1 Field observations

The river network, along with its tributaries, and existing land use pattern in the basin, as identified during the field winter reconnaissance, are depicted in Figure 1. The hydrology, hydrogeology and geology of the upper Litani basin, and details on Canal 900 are described in the winter technical survey report (USAID, 2005b). Field summer reconnaissance visits verified the presence of the various sources of pollution identified during the winter reconnaissance along the Litani river and its tributaries (Figure 2) (refer to Appendix B for a list of observed sources of pollution). As discerned in the winter survey, the sources vary between domestic wastewater discharge, industrial effluent, and solid waste landfill/disposal sites (Figure 3). Again, it was observed that wastewater/industrial effluents are still being directly discharged into the Litani river and its tributaries without prior treatment.

In general, the flow of the water in the Litani river was observed to be considerably low (Figure 4). While the high evaporation rate and low water flow from spring sources in the summer season contribute notably to this condition, several observed practices at various locations along the litani river and its tributaries including direct water pumping via pumps installed at the river bank, water diversion through earthern canals for irrigation, and/or intentional blocking of the natural river flow for water collection purposes are also affecting the water flow in the river (Figure 5). These factors and practices are resulting in a minimum quantity of water reaching the Qaraoun Lake.

Site visits to Canal 900 (July 2005) revealed a notable decrease of algae proliferation with various degrees of algae accumulation at different sections of the canal, ranging from no accumulation at the beginning of the canal, to insignificant growth midway through the canal, to relatively high growth of algae and aquatic weeds towards the canal’s dead end in Kamed El Laouz (Figure 6). The decrease in algae proliferation can be attributed to the control program using copper sulfate that started in May 2005 as part of this on-going project.

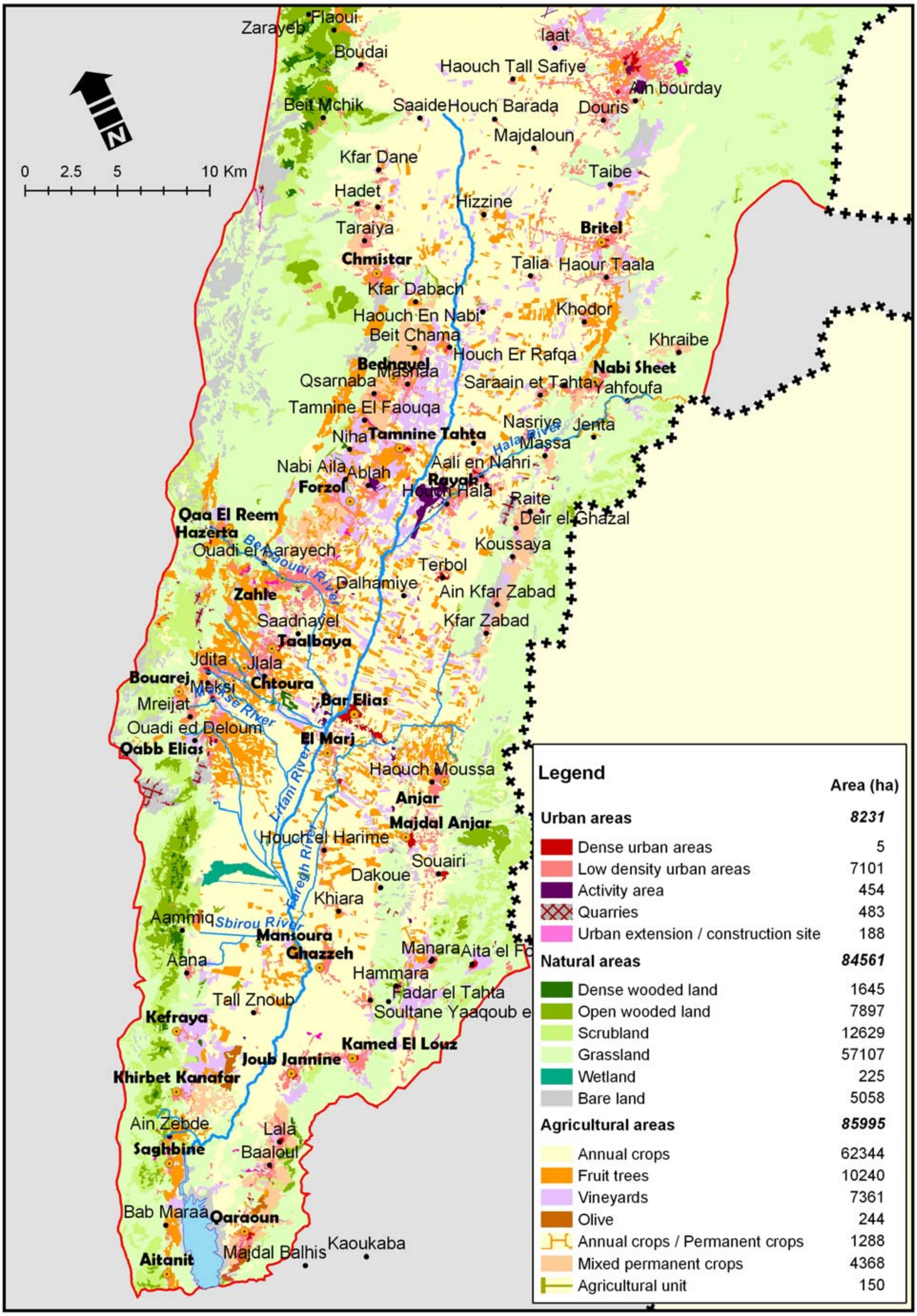


Figure 1. Litani river and its tributaries with existing land use in the upper basin

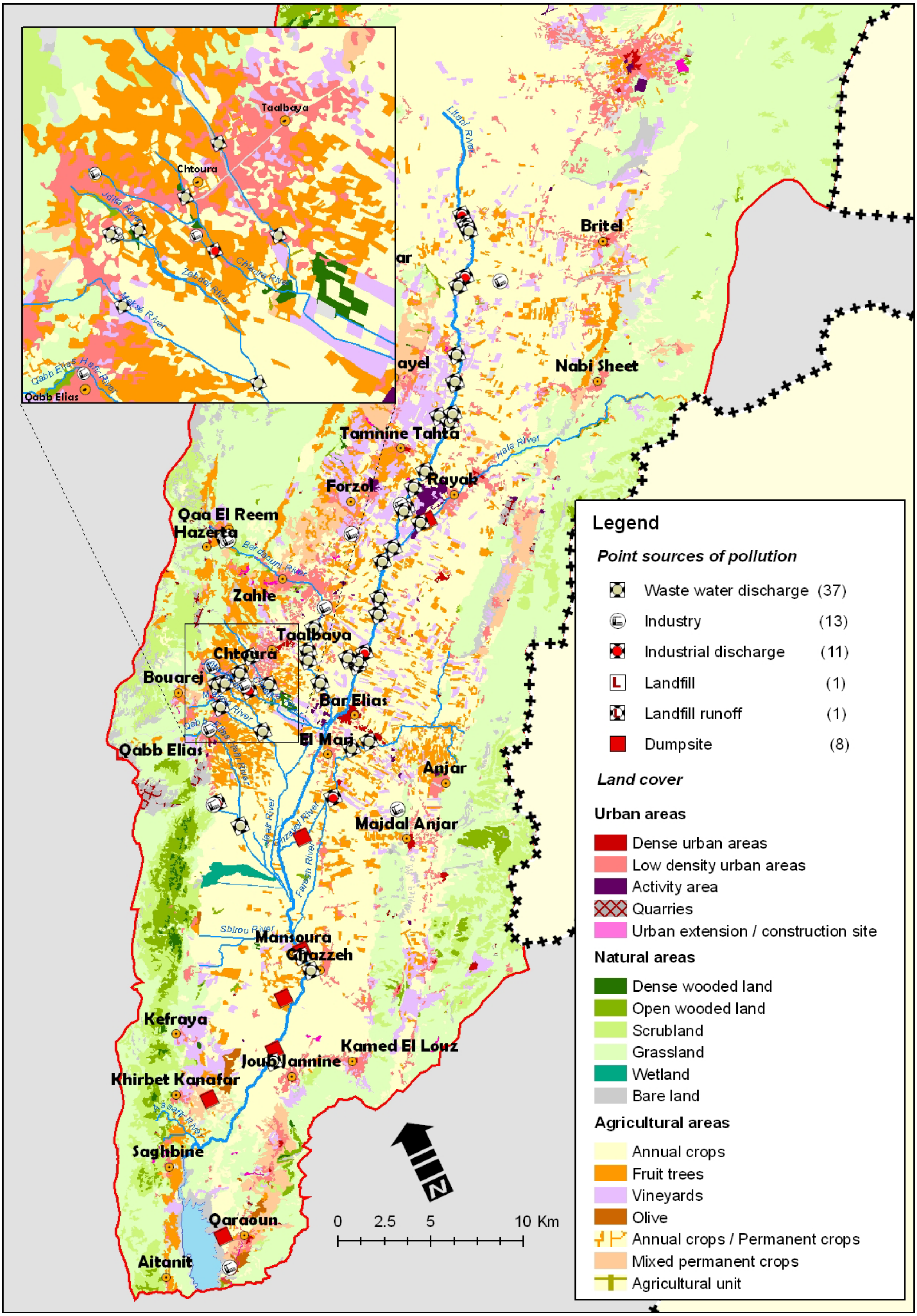


Figure 2. Point and non-point sources of pollution documented during the field surveys

Domestic wastewater
(Bednayel, Litani river)

Industrial discharge (Tanmiya facility)
(Ablah, Litani river)

Landfill (Zahle, Litani river)

Dumpsite (Qsarnaba, Litani river)

Figure 3. Examples/types of point sources of pollution documented during the field surveys

Summer (June 2005)

Winter (February-March 2005)

Joint of combined Berdaouni-Chtaura with Litani

Summer (June 2005)

Winter (February-March 2005)

Litani river, Joub Jannine bridge

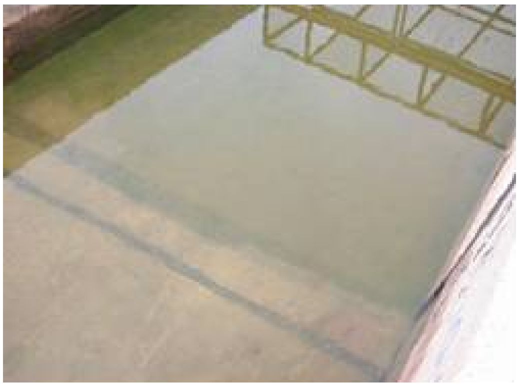
Figure 4. Change of flow in Litani river between winter and summer site visits

Water diversion

Direct pumping

Intentional blocking

Figure 5. Observed practices contributing to decrease in river flow



No algae growth
(start point)

Insignificant algae accumulation
(mid way)

Increased accumulation
(towards dead end)

Figure 6. Change of algae profileration along the length of Canal 900

1.2 Rationale for sample selection

The rapid review (USAID, 2005a) defined a sampling program for the upper Litani basin to complement or fill in the gaps of previous and on-going monitoring activities in the basin. The program included two sampling rounds in winter (USAID, 2005b) and summer. The summer sampling program comprises the collection of water samples from the Litani river and its tributaries, groundwater samples throughout the basin, water samples from Canal 900, water and fish samples from the Qaraoun lake, and soil and crop samples from irrigation areas adjacent to Canal 900. To the extent feasible, samples were collected from the same locations selected during the winter sampling program. The rationale for selecting these sample locations is outlined below within the context of the timeframe allocated to the field surveys and resource constraints.

Surface water

Water sampling along the upper sections of the Litani river and its tributaries focused on assessing the potential impacts resulting from effluent discharges along the river. Wherever feasible, effluent samples were collected at the point of discharge, and at distances ranging between 100 and 500 meters downstream or upstream of a discharge point depending on accessibility. Similarly, samples were collected at confluence points from tributaries and the main river course at locations upstream and downstream of the confluence point. On the other hand, for stretches of the river where no effluent discharges were observed, samples were collected at various distances in an attempt to characterize the river water quality along these stretches. Around 23 domestic and industrial effluent samples were collected from discharge points, 12 samples from spring sources, and 69 river water samples were collected from 64 locations along the river. All 104 samples underwent partial analysis (physico-chemical and microbiological) as detailed in Section 2.1. The sampled locations along the Litani river and its tributaries are presented in Figure 7. Appendix C presents a brief description of the sampled locations.

Groundwater

The groundwater sampling campaign aimed at characterizing the prevailing groundwater quality within the upper Litani basin during the summer season. The 60 sampled wells were selected based on the sources of potential pollution identified during the reconnaissance field surveys, the land use map of the basin area, accessibility, and adequate spatial representation. In this context, typical locations targeted areas with extensive agricultural activities, areas near solid waste dumpsites or landfills, and remote areas with minimal human activities representing background conditions. The geographic distribution of sampled groundwater wells is presented in Figure 8 together with the type of analysis whereby 50 wells underwent partial analysis (physico-chemical and microbiological) and the other 10 underwent full analysis (physico-chemical, microbiological, heavy metals, and pesticides). Most sampled wells are in the Beqaa Valley, thus tapping into the Neogene-Quaternary aquifer at a depth of 70 to 100 m below ground surface, with the exception of the wells to the south-east of the axis Ghazzeh – Joubb Jannine, 4 wells are tapping in the Eocene, 11 in the Cenomanian and 3 in Khirbet Qanafar and Kefraya in the Jurassic[1]. Appendix D presents a brief description of the sampled wells.

[1] The Eocene and Cenomanian aquifers are both karstified. Where these formations are exposed, they offer preferential flow path leading directly to the aquifer which reduces the residence time in the vadoze zone. On the other hand, the Neogene-Quaternary aquifer is composed of alluvia with lower hydraulic conductivity providing higher resistance for water movement and longer residence time in the vadoze zone, hence allowing physical, biological, and chemical processes to take place leading to natural degradation of the pollutants, mainly pesticides which are degraded by biological processes, and any eventual heavy metals adsorbed by soil layers.

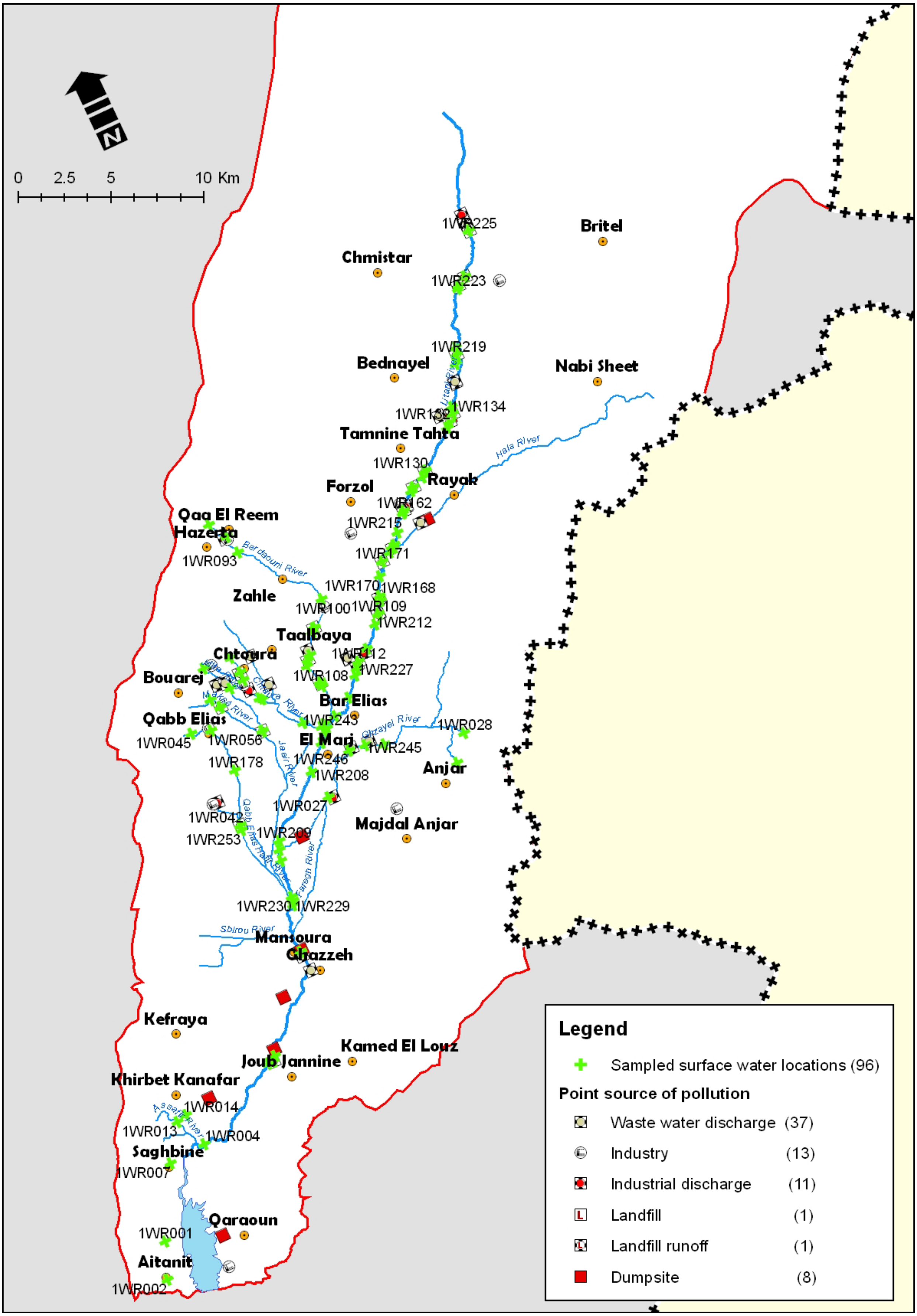


Figure 7. Location of water samples collected along the Litani river and its tributaries

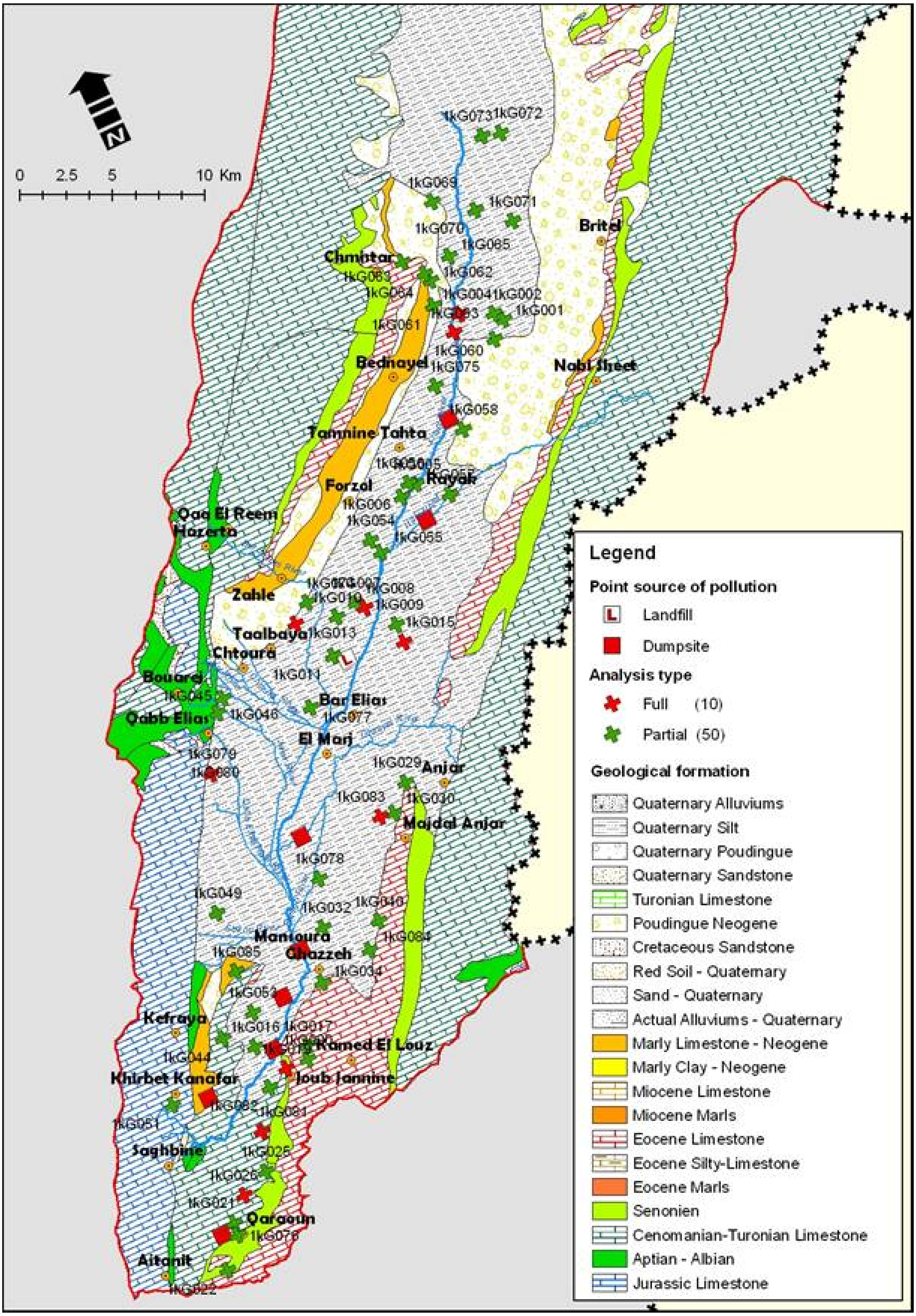


Figure 8. Location of sampled groundwater wells with corresponding analysis type

Lake water and fish

The sampling locations were selected to represent the whole water body in the lake. In this context, 30 samples were collected from 20 locations over the lake area as depicted in Figure 10. The water column at locations near the dam with greater depths was sampled at two depths (10 samples at 1/3 and 10 samples at 2/3 from the top); while at shallower locations 10 samples at mid depth were collected. The samples taken at 2/3 of the depth underwent partial analysis (physico-chemical and microbiological), while the others underwent full analysis (physico-chemical, microbiological, and heavy metals). A total of 6 fishes were also collected from the lake using a net deployed by a local fisherman. The fish were analysed for copper, cadmium and chromium.

Canal 900

The samples were selected to represent the water quality along the Canal. Accordingly, 12 samples were collected from the three sections of the Canal behind the flow control gates and from the last stretch between the dead end at Kamed El Laouz and the last flow control gate in Joub Jannine. Moreover, it was also intended to assess the quality of the water that is ultimately being used by farmers for irrigation. For that reason, 3 water samples were collected from the regulating reservoirs of Canal 900 (Figure 9), and 5 samples from irrigation outlets in the irrigated zones. All underwent partial analysis (physico-chemical and microbiological). In addition, 4 samples were collected from locations where copper sulfate was added as part of the ongoing algae control program. These samples were analyzed for the same parameters used in this program for quality control purposes, in addition to selected indicators of heavy metals. The locations of water samples along the Canal are presented in Figure 11.

Qaraoun

Lala-Baaloul

Joub Jannine

Figure 9. Regulating reservoirs along Canal 900

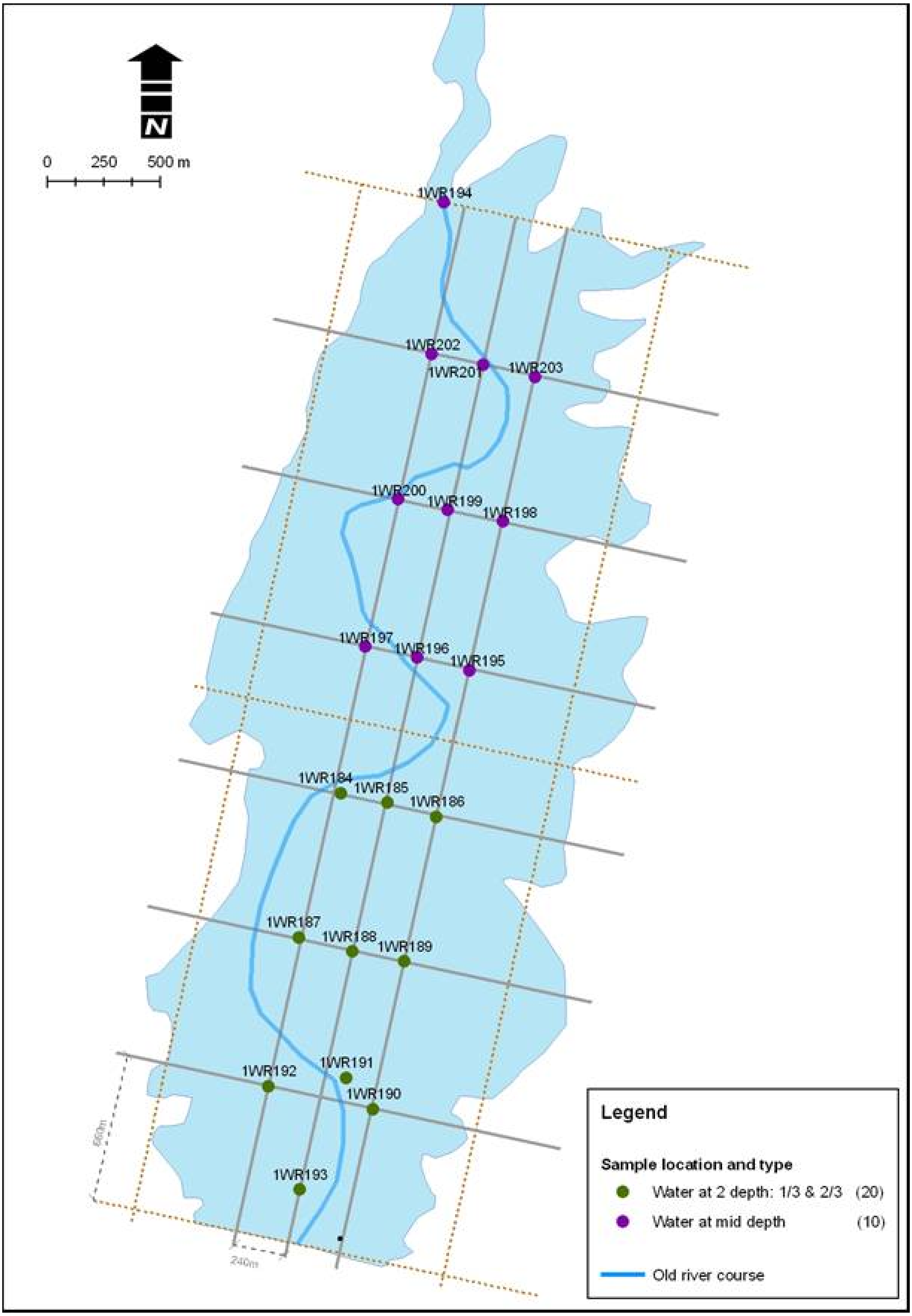


Figure 10. Location of water samples collected from the Qaraoun lake

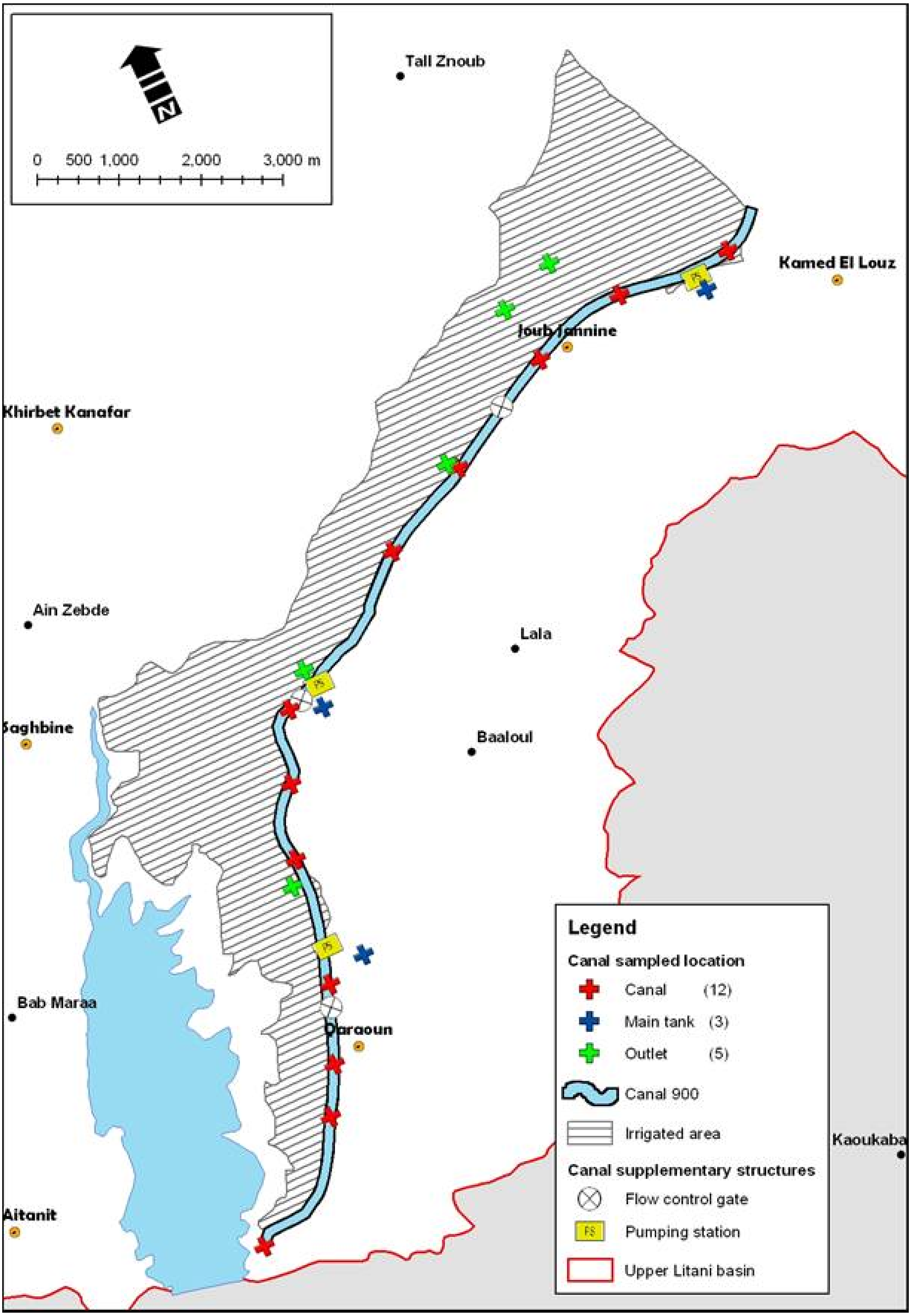


Figure 11. Location of water samples collected along Canal 900

Soil

Soil sampling in the upper sections of the Litani basin and in the agricultural lands along Canal 900 aimed at assessing the potential impacts on soil quality as a result of using the Litani water for irrigation. Accordingly, 25 soil samples were collected from the three agricultural zones irrigated from Canal 900 (Scheme 1-Qaraoun, Scheme 2-Lala, and Scheme 3-Joub Jannine-Kamed El Laouz), and 5 more samples were collected from the agricultural area near the diversion point from the Yammouneh irrigation canal (Scheme 4), which could be considered as background samples. All samples underwent analysis for selected heavy metals. The locations of collected soil samples are depicted in Figure 12. Appendix E presents a brief description of the sampled locations.

Crop

The crop samples were selected to assess the potential future impact on copper content in crops as a result of implementing the algae control program (copper sulfate treatment) in Canal 900. As such, 15 crop samples were collected from the three irrigated schemes of the canal and underwent analysis for copper content. Chromium and cadmium content of crops was also analyzed. The crop type was selected to be representative of the irrigated area. Appendix F presents a brief description of type of crop sampled, irrigation water source, and locations.

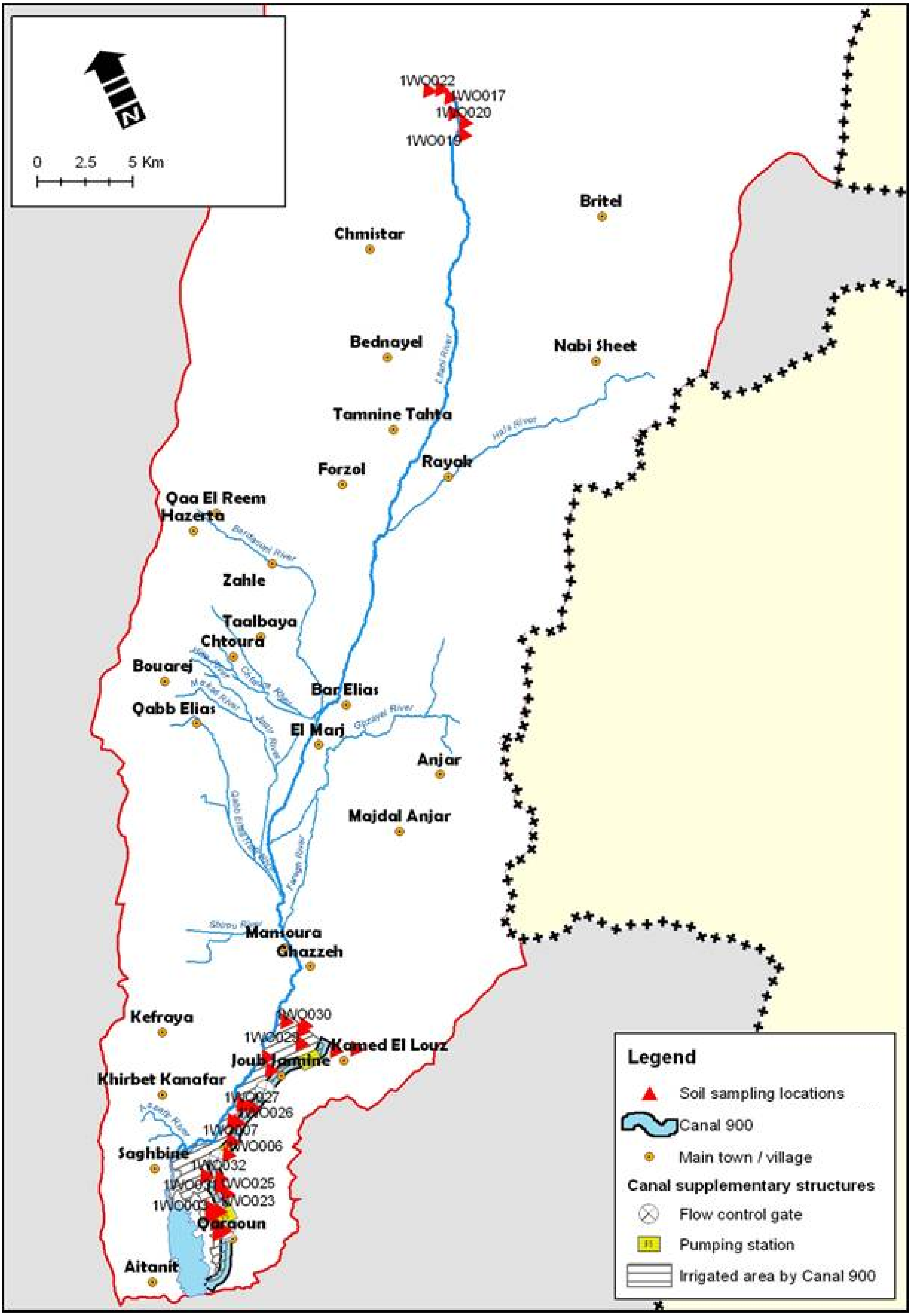


Figure 12. Soil sampling locations

A summary of the number of samples collected during the summer sampling program with their corresponding selection rationale is presented in Table 1.

Table 1. Summary of samples collected with corresponding locations

Type	*No. of samples collected*	*General location*
Surface water	104	❑ Upstream and downstream of confluence and discharge points ❑ At distances along river stretches
Ground water	60	❑ Near potential sources of pollution (i.e. solid waste dumpsites/ landfills) ❑ In areas with intensive agricultural activities ❑ Remote areas with minimal human activities ❑ Spatially distributed in the upper basin area
Canal 900	20	❑ The three Canal sections behind each flow control gate ❑ The last section between the dead end and last flow control gate ❑ The regulating reservoirs of the canal ❑ Irrigation outlets from the irrigated schemes
Qaraoun lake	30	❑ At mid depth in shallow zones ❑ At 1/3 and 2/3 depth in deeper zones ❑ Spatial distribution over the lake area
Soil	30	❑ The three irrigated schemes of Canal 900 ❑ Background samples from Saaide area near diversion from Yammouneh Agricultural Canal
Fish	6 fishes	❑ From the Qaraoun Lake
Crop	15	❑ The three irrigated schemes of Canal 900

2. WATER QUALITY ASSESMENT

2.1 Sample collection and analysis

Surface water (river and canal) samples were collected directly through bottle immersion at shallow depths. Groundwater samples were collected from a well, after allowing the water to flow for about 10 to 15 minutes, to ensure proper flushing. Samples for pesticides analysis were collected in amber sterile glass bottles. Samples for bacteriological and chemical analysis were collected in sterile glass and plastic bottles, respectively, and those for heavy metals analysis were collected in sterile plastic bottles preserved with acid (70 % Nitric acid). In all cases, sample collection, transport, holding and handling, as well as subsequent analysis were conducted in accordance to the “Standard Methods for the Examination of Water and Wastewater” as approved by the American Public Health Association, Water Environment Federation, and American Water Works Association. The adopted guidelines for sample collection are presented in Appendix G. Water samples from the Qaraoun Lake were collected using a vertical deep water sampler. Soil samples were collected using a soil auger from a depth ranging between 10 and 30 cm below surface. Several samples were extracted from the land plot to form a composite sample.

The collected samples (surface water – river, lake, and Canal 900 –, groundwater, soil, crop, and fish) were analyzed for a pre-defined set of bacteriological, physical, and chemical parameters at the laboratories of the American University of Beirut (AUB). Table 2 presents the type of analysis conducted on the various samples. Analysis for heavy metals on soil and crop samples and pesticides on groundwater samples were conducted at the Environmental Core Laboratory (ECL). The remaining analyses were conducted at the Environmental

Engineering Research Center (EERC) to ensure timely sample analysis within a tight timeframe. Delivered samples to either laboratories were recorded on a daily log sheet (Appendix A) which serves as a chain of custody record. Moreover, onsite measurements of water pH, temperature, and dissolved oxygen (DO) were conducted using a portable pH-temperature meter (Cole Parmer, model no. 59002-00) and a portable microprocessor dissolved oxygen meter (Hanna Instruments, model no. HI9143). The environmental significance of analyzed parameters, and the analytical methodologies and reference methods are presented in Table 3.

Table 2. Type of analysis conducted on the various samples collected

Matrix	*Analysis type*	
	Type I- Full Analysis	*Type II- Partial Analysis*
River water Lake water Canal water Industrial wastewater Domestic wastewater	▪ Total coliform ▪ Fecal coliform ▪ Nitrates ▪ Phosphates ▪ Sulfates ▪ Ammonia ▪ Total dissolved solid ▪ BOD ▪ COD ▪ Lead ▪ Cadmium ▪ Chromium	▪ Total coliform ▪ Fecal coliform ▪ Nitrates ▪ Phosphates ▪ Sulfates ▪ Ammonia ▪ Total dissolved solid ▪ BOD ▪ COD
No. of samples	*20*	*134*
Groundwater	▪ Total coliform ▪ Fecal coliform ▪ Nitrates ▪ Phosphates ▪ Sulfates ▪ Nickel ▪ Copper ▪ Zinc ▪ Lead ▪ Cadmium ▪ Chromium ▪ Organochlorines ▪ Organophosphorous	▪ Total coliform ▪ Fecal coliform ▪ Nitrates ▪ Phosphates ▪ Sulfates
No. of samples	*10*	*50*
Soil	▪ Copper ▪ Cadmium ▪ Chromium	
No. of samples	*30*	
Fish tissue	▪ Copper ▪ Cadmium ▪ Chromium	
No. of samples	*9*	
Crop	▪ Copper ▪ Cadmium ▪ Chromium	
No. of samples	*15*	

Table 3. Analytical techniques and reference methods

Parameter	*Significance*	*Test type*	*Method reference*
pH	Indication of stress on aquatic life	Electrometry	SM 4500-H^+B
Dissolved oxygen	Indication of pollution by organic matter	Electrometry	SM 4500-OE
Conductivity/TDS	Indication of the presence of mineral salts	Electrometry	SM 2510B
Nitrate	Indication of fertilizer seepage	Colorimetry	SM 4500 $NO3^-$B
Phosphate	Indication of fertilizer seepage	Colorimetry	SM 4500-PE
Sulfate	Indication of industrial pollution	Colorimetry	SM 4500-SO4
Heavy metals	Indication of industrial pollution	Gas chromatography	EPA 200.8
BOD	Indication of domestic or industrial wastewater contamination	Membrane electrometry	SM 5210B
COD	Indication of domestic or industrial wastewater contamination	Closed reflux /coloremetry	SM 5220D
Ammonia	Indication of domestic or industrial wastewater contamination	Colormetry	HACH® method 8155
Total coliform	Indication of the presence of disease-causing microorganisms	Membrane filtration	SM 9222B
Fecal coliform	Verification of wastewater contamination and the indication of the presence of disease-causing organisms	Membrane filtration	SM 9222D
Pesticides (Organo-phosphates & Organochlorines)	Indication of agricultural pollution	Gas chromatography	EPA 507 & 608

2.2 Results and discussion

Water samples from the Litani River and its tributaries, Qaraoun Lake, Canal 900, and groundwater wells were analyzed for the indicators outlined above and the results were compared with national and international standards for different uses (Table 4). The complete laboratory analysis results for water (surface and ground), soil, crop, and fish samples are presented in Appendix H.

Table 4. Summary of National and International water quality guidelines

Parameters	*Drinking water standard*			*Reclaimed wastewater for irrigation*								*USEPA (1992)*	
	MoE-Lebanon		*USEPA*	*MoE proposed guidelines (2005)*									
	GV[1] (20°C)	*GV[1] (25°C)*	*GV/MAL[2]*	*Class 1A[7]*		*Class 1B[7]*		*Class 2[7]*		*Class 3[7]*		*Long term*	*Short term*
				Avg	*Max*	*Avg*	*Max*	*Avg*	*Max*	*Avg*	*Max*		
pH (pH units)	6.5-8.5	6.5-8.5	6.5-8.5	-		-		-		-		-	-
Temperature (°C)	12	NA[3]	NA	-		-		-		-		-	-
Total dissolved solids (mg/L)	400[4]	500[5]	500[5]	-		-		-		-		-	-
Dissolved oxygen (mg/L O_2)	NA	NA	NA	-		-		-		-		-	-
Ammonia (mg/l)	0.05 (as NH_4^+)	NA	NA	-		-		-		-		-	-
Phosphates (mg/L)	0.4 (as P_2O_5)	NA	NA	-		-		-		-		-	-
Nitrate (mg/L)	25	10 (as N)	10 (as N)	-		-		-		-		-	-
Sulfate (mg/L)	25	250	250	-		-		-		-		-	-
Biochemical oxygen demand (mg/L)	NA	NA	NA	10	15	25	40	30	45	30	45	-	-
Chemical oxygen demand (mg/L)	NA	NA	NA	-		-		-		-		-	-
Fecal coliforms (CFU[6]/100, ml)	0/100	0/100	0/100	5	23	100	200	200	400	1,000	2,000	-	-
Total coliforms (CFU[6]100, ml)	0/100	0/100	0/100	-		-		-		-		-	-
Heavy metals	-	-	-	-		-		-		-		-	-
Zinc (mg/l)	-	-	-	-		-		-		-		2	10
Copper (mg/l)	-	-	-	-		-		-		-		0.2	5
Cadmium (mg/l)	-	-	-	-		-		-		-		0.01	2
Chromium (mg/l)	-	-	-	-		-		-		-		0.1	1
Lead (mg/l)	-	-	-	-		-		-		-		5	10

[1] GV: Guideline value
[2] MAL: Maximum admissible level ; USEPA: US Environmental Protection Agency
[3] NA: Not applicable
[4] reference temperature at 20°C
[5] reference temperature at 25°C
[6] CFU: colony forming unit
[7] Avg= 30 day average, Max= Maximum, see description of classes

Class of Reclaimed Wastewater	**Spray Irrigation**	**Flood Irrigation and Surface Drip Irrigation**
Class 1A	• No access control • No setback to dwelling unit or occupied establishment	• No access control
Class 1B	• No access control; irrigate at times when public exposure is unlikely • 50 meter set-back from dwelling unit or occupied establishment	• No access control; irrigate at times when public exposure is unlikely
Class2	• Access restricted by perimeter fencing using 4-strand barbed wire and locking gate • 50 meter set-back from dwelling unit or occupied establishment	• Access restricted by perimeter fencing using 4-strand barbed wire and locking gate
Class 3	• Access restricted by perimeter fencing using 4-strand barbed wire and locking gate • 250 meter set-back from dwelling unit or occupied establishment • Low pressure/low trajectory irrigation system only	• Access restricted by perimeter fencing using 4-strand barbed wire and locking gate • 50 meter set-back to dwelling unit or occupied establishment

2.2.1 Surface Water

More than 92 percent of water samples collected along the Litani river and its tributaries exhibited levels of Total and Fecal Coliforms exceeding significantly the MoE guidelines for domestic use (Figure 16). Total coliform levels ranged between 2 and 1,500,000 CFU/100ml, with an average of around 308,400 CFU/100ml. Similarly, fecal coliform levels ranged between 0 and 1,500,000 CFU/100ml, with an average of around 224,100 CFU/100ml (Figure 13 and Figure 14). Such high levels correspond to untreated domestic wastewater discharge into the river, coupled with low dilution in the summer season. Moreover, high levels of total and fecal coliforms exceeding the standard were also detected at spring sources. For instance, total and fecal coliform levels of 52 and 31 CFU/100ml, 79 and 16 CFU/100ml, and 200 and 13 CFU/100ml were detected in Chamsine, Qabb Elias, and Jdita springs, respectively. Similarly, ammonia levels, which are also correlated with domestic wastewater discharge, exceeded acceptable standards in 87 percent of the samples (Figure 16). High BOD levels were also detected along several stretches of the river (upstream of Al Marj area), which was expected given the high volumes of domestic wastewater discharged without prior treatment (Figure 15). The highest levels of contamination along the river fall within the mid-upper Litani basin where the largest communities are located and are discharging into the river and prioir to the dilution effect from various tributaries. While sulfate levels were acceptable all along the river, nitrate and phosphate levels exceeded recommended standards in 8 and 68 percent of the samples, respectively (Figure 16). Furthermore, similar to BOD levels, high nitrate and phosphate levels were mostly detected upstream of El Marj area prior to the dilution effect from the various tributaries.

When compared with reclaimed wastewater guidelines for irrigation as proposed by the Lebanese MoE, 72 to 86 percent of the samples exhibited Fecal coliform levels exceeding the threshold set for Class 3 and Class1A, respectively and 22 to 33 percent of the samples had a BOD level exceeding the threshold for the same classes (Figure 17 and Figure 18). Hence, direct irrigation from the river water is clearly not advisable.

Out of the 76 river sample locations, 73 were sampled during both the winter and summer rounds. Comparison of the summer results for the 73 samples with their winter counterpart revealed that the total coliform levels more than doubled in 71 percent of the samples (Figure 20). Similarly, fecal coliform levels increased in 66 percent of the samples by more than 50 percent, and more than doubled in 63 percent of the samples. Phosphate levels also increased by more than 50 percent and more than doubled in 84 and 78 percent of the samples, respectively.

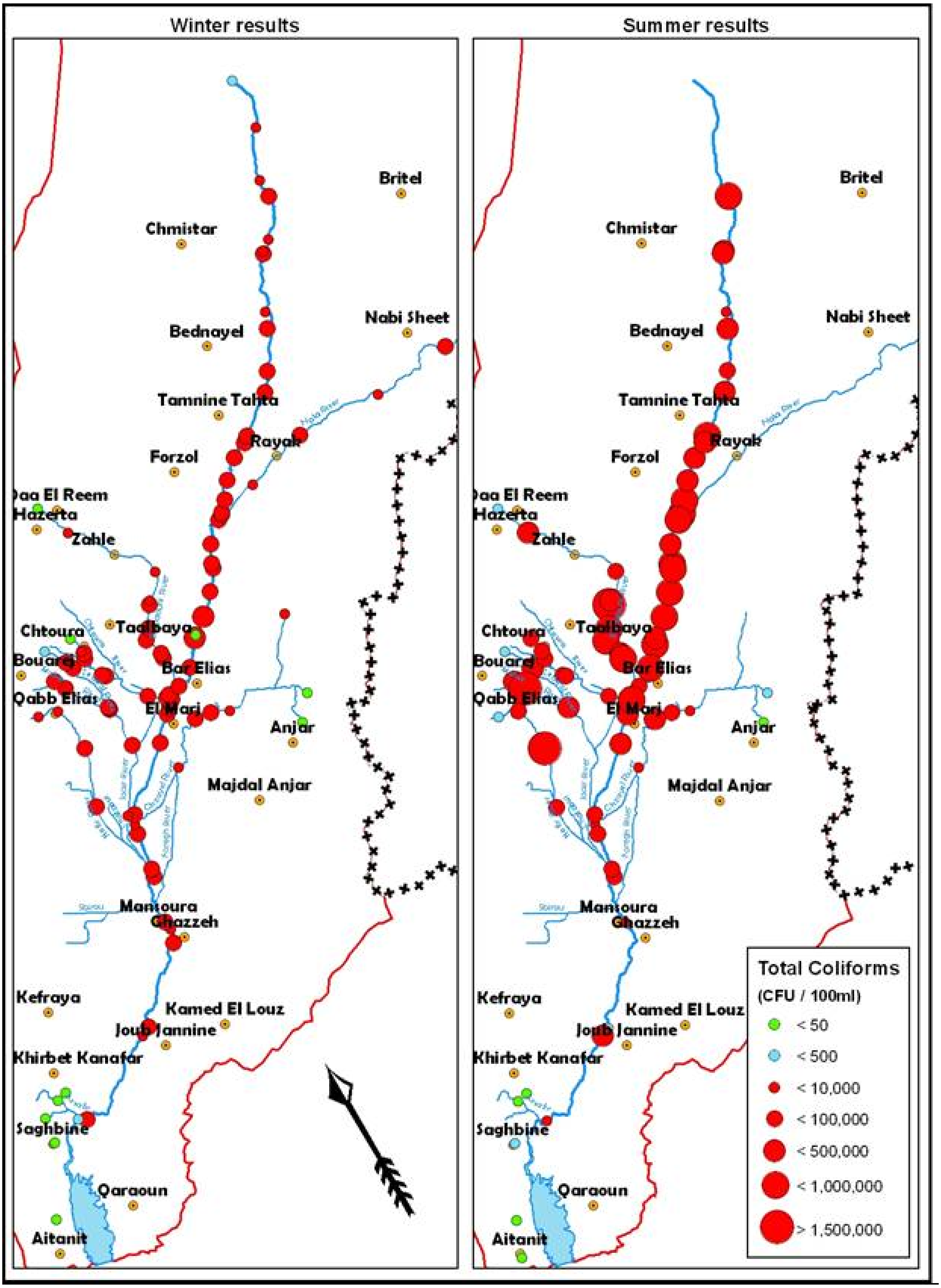


Figure 13. Analysis results for water samples along the Litani River and its tributaries (Total Coliform)

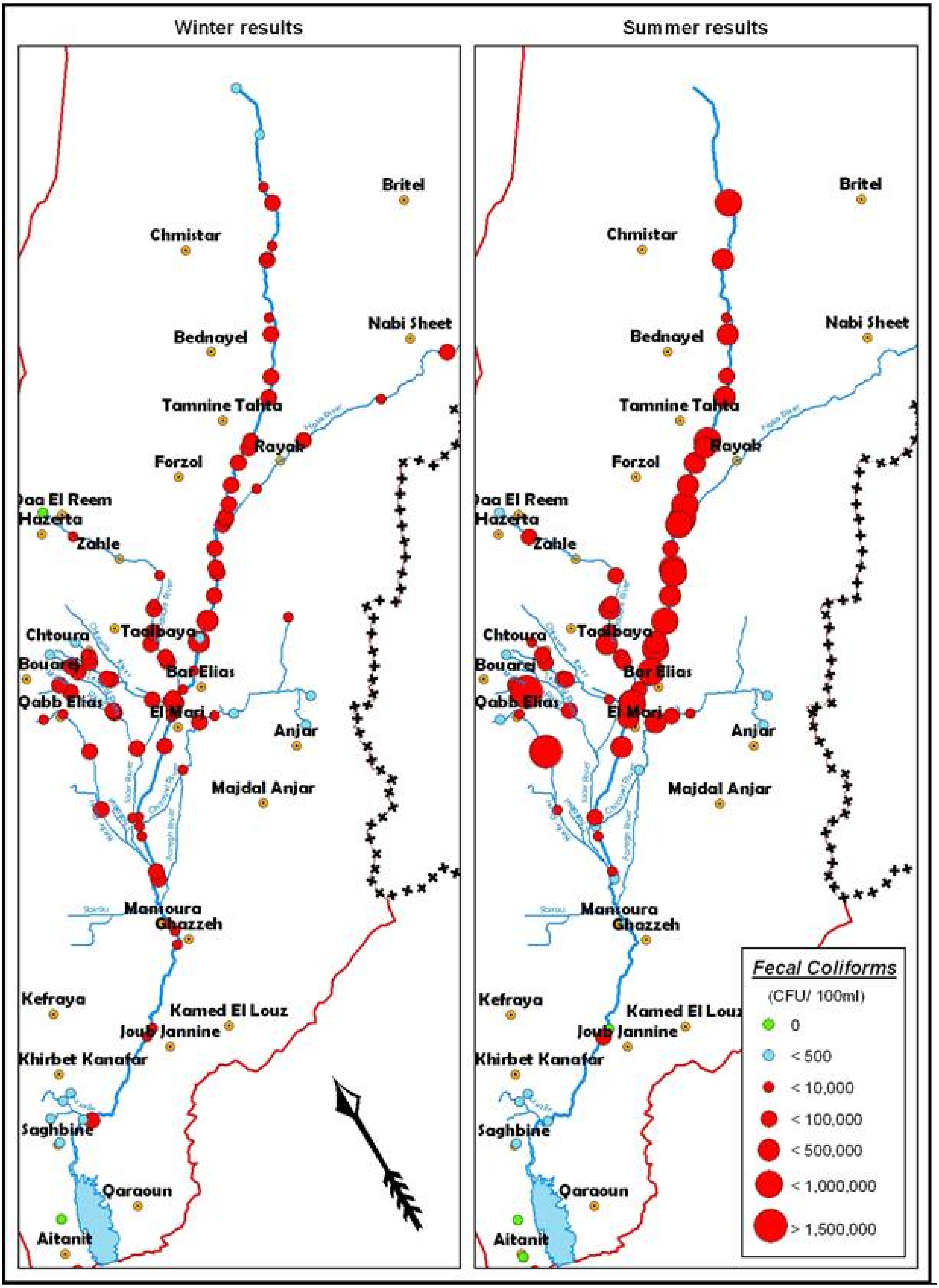


Figure 14. Analysis results for water samples collected along Litani river and its tributaries (Fecal coliform)

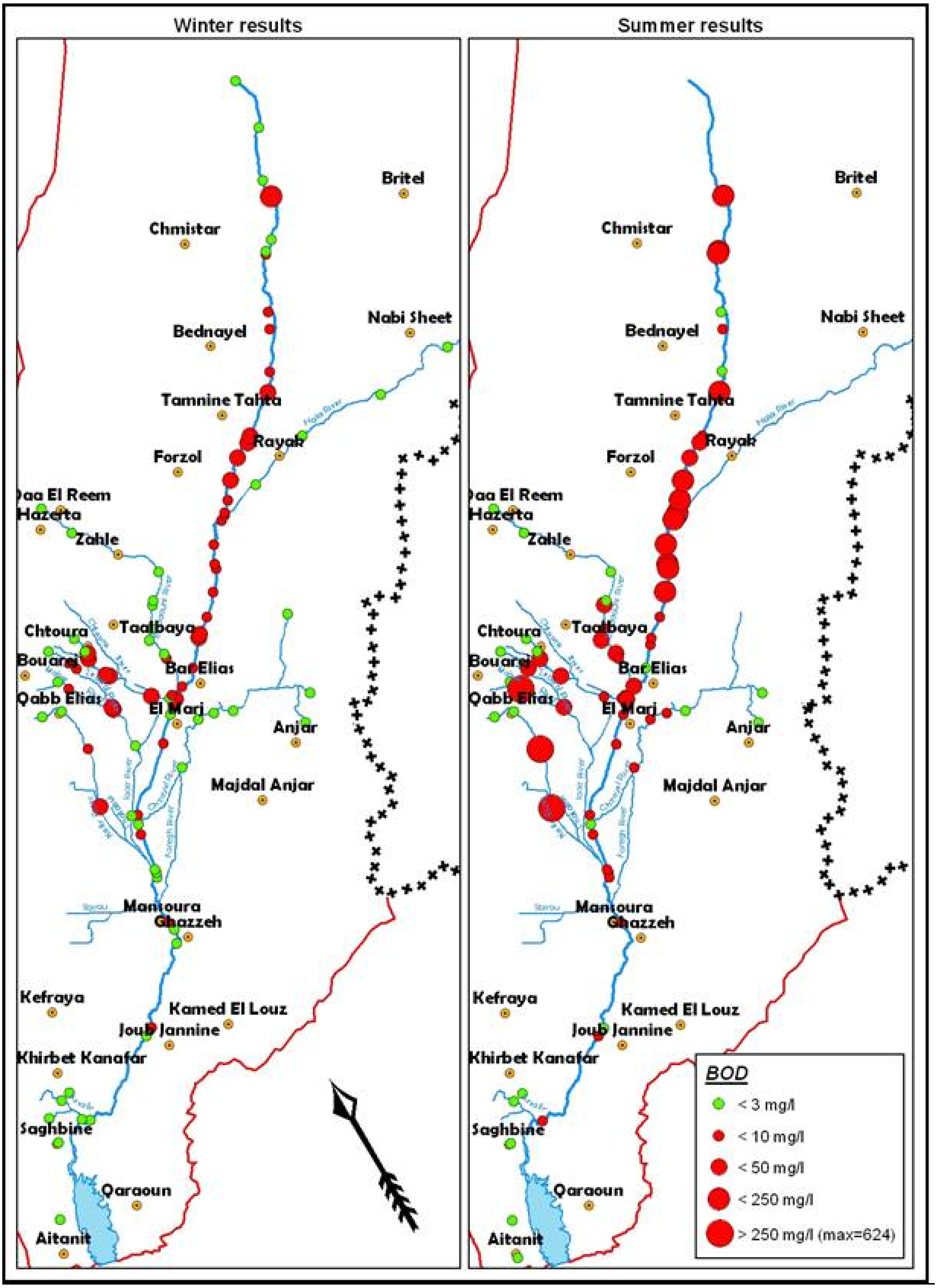


Figure 15. Analysis results for water samples along the Litani River and its tributaries (BOD)

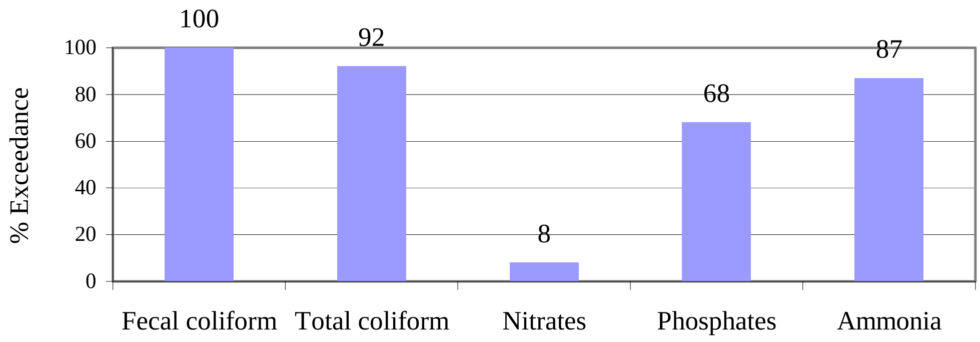


Figure 16. Percentage of samples along the Litani River and tributaries exceeding MoE water quality standards for domestic use

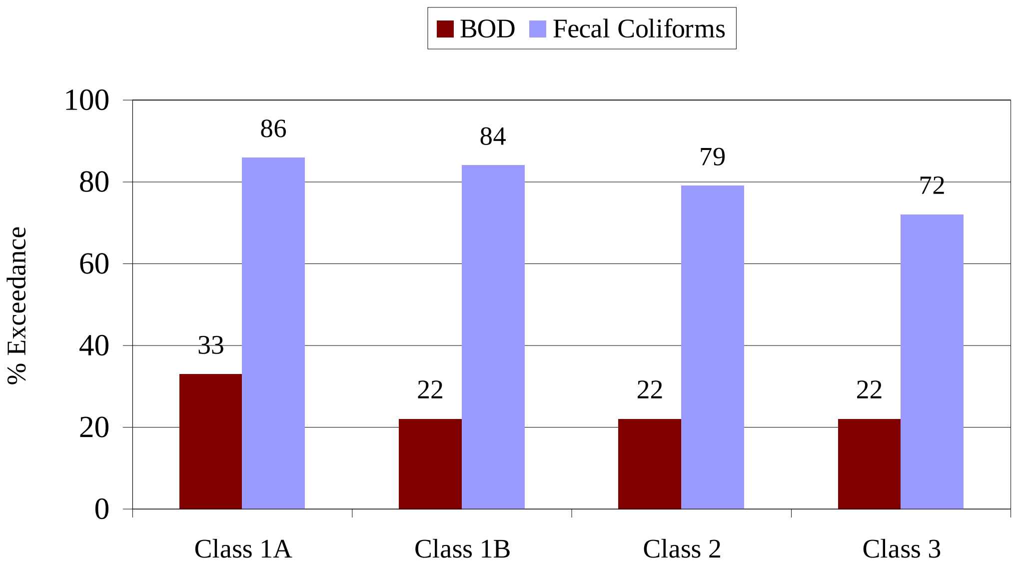


Figure 17. Percentage of samples along the Litani River and tributaries exceeding proposed Lebanese MoE water quality guidelines for irrigation

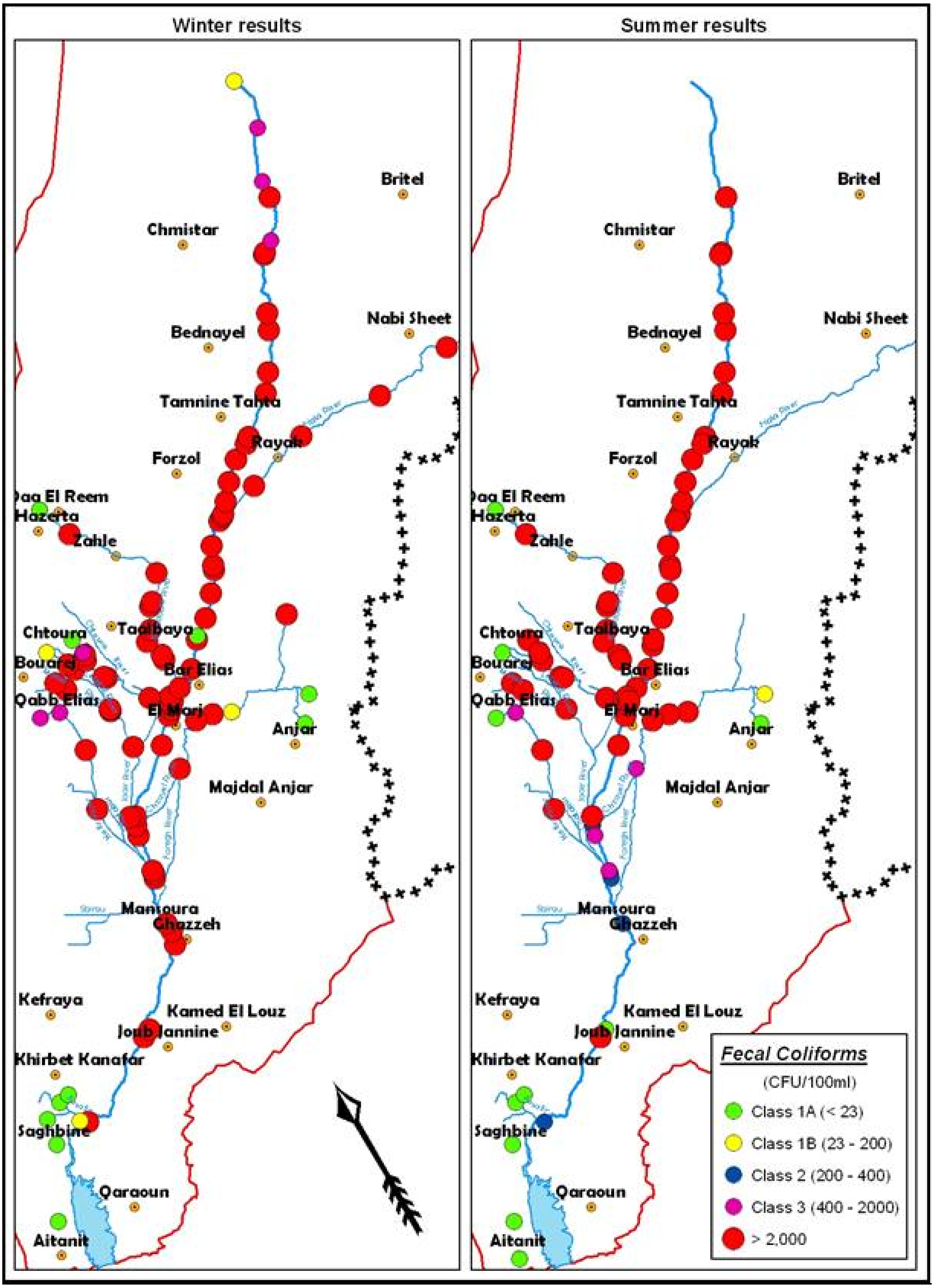


Figure 18. Analysis results of water samples along the Litani river and its tributaries (Fecal Coliform) based on the classes of the proposed Lebanese MoE water quality guidelines for irrigation

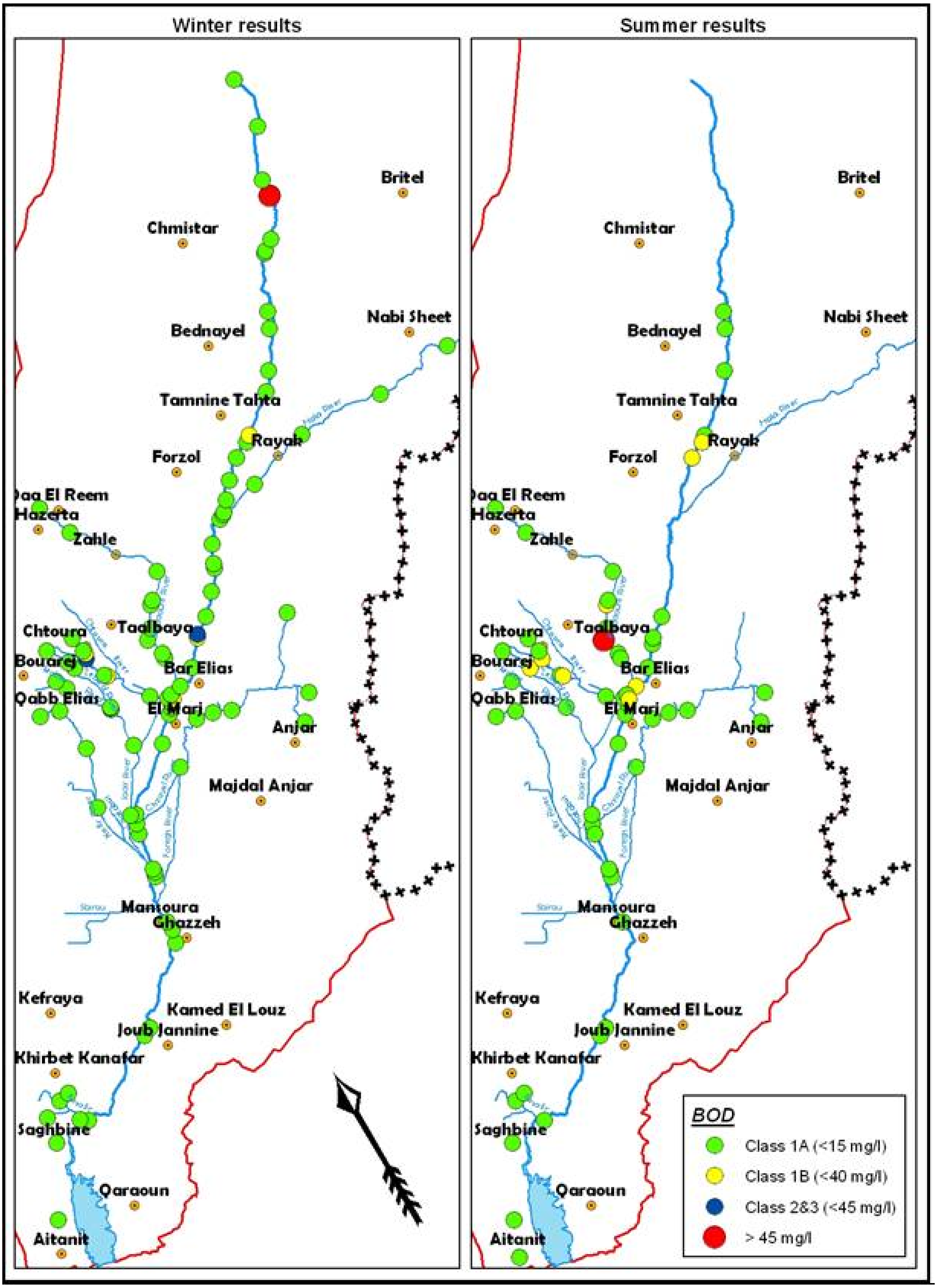


Figure 19. Analysis results of water samples along the Litani river and its tributaries (BOD) based on the classes of the proposed Lebanese MoE water quality guidelines for irrigation

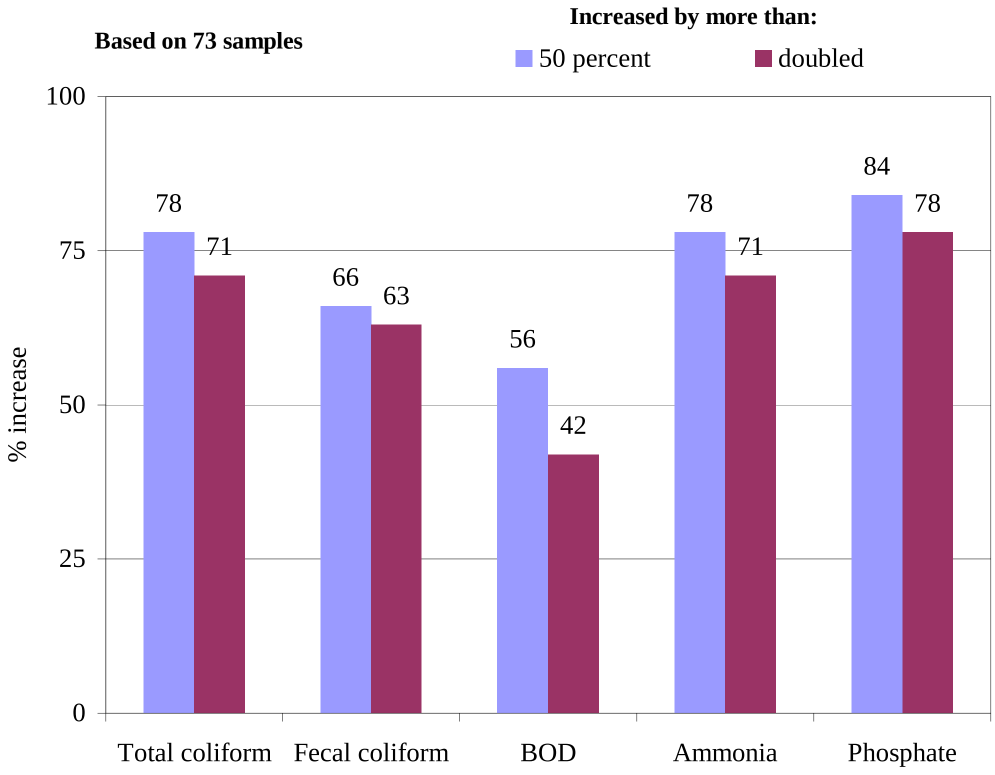


Figure 20. Comparison between winter and summer results for river samples

2.2.2 Qaraoun Lake

Lake water samples exhibited total and fecal coliform and ammonia levels exceeding drinking water standards in 7, 17, and 93 percent of the samples, respectively (Figure 21). Phosphate and sulfate levels were acceptable in the Lake water samples. On the other hand, nitrate levels in only 7 percent of the lake samples exceeded the standards. When compared with reclaimed wastewater guidelines for irrigation as proposed by the Lebanese Ministry of Environment, all water samples from Qaraoun Lake were within the BOD and FC thresholds for classes 1A, 1B, 2, and 3, except at two instances where the fecal coliform count reaches 53 and 450 CFU/100ml (Figure 23 and Figure 24). Heavy metals (chromium, cadmium, and copper) were reported to be below detection limits. The analysis results for lake water samples are presented in Appendix H.

If compared with the winter sampling results, the average total coliform level in the summer decreased fom 64 to 23 CFU/100ml, while that for fecal coliform decreased from 39 to 17 CFU/100ml (Figure 22). Likewise, the summer average ammonia level drops from 0.62 to 0.3 mg/l and the average for nitrates drops from 27.9 to 21.67 mg/L. This decrease can be attributed to the fact that the levels of pollutants in the Lake during summer are governed mainly by Lake dynamics (dilution, stratification, currents, sedimentation), particularly that the river-lake system is interrupted by the low flow of contaminant-laden water into the Lake as observed during the summer reconnaissance phase.

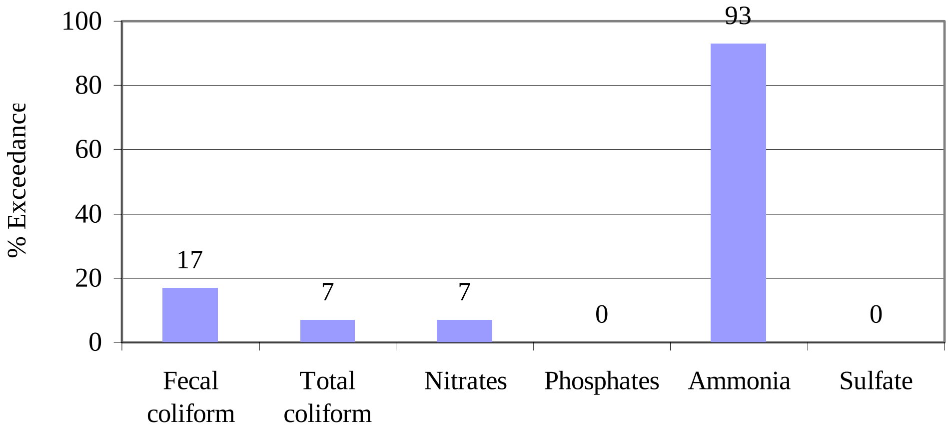


Figure 21. Percentage of samples from the Qaraoun Lake exceeding Lebanese MoE water quality standards for domestic use

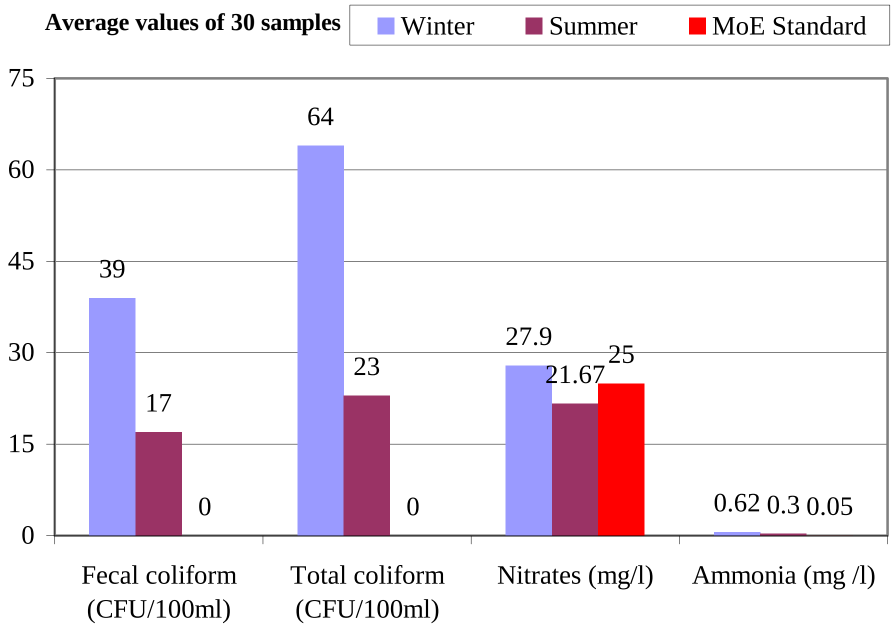


Figure 22. Comparison between winter and summer average results of FC, TC, Nitrates, and Ammonia for Lake water samples

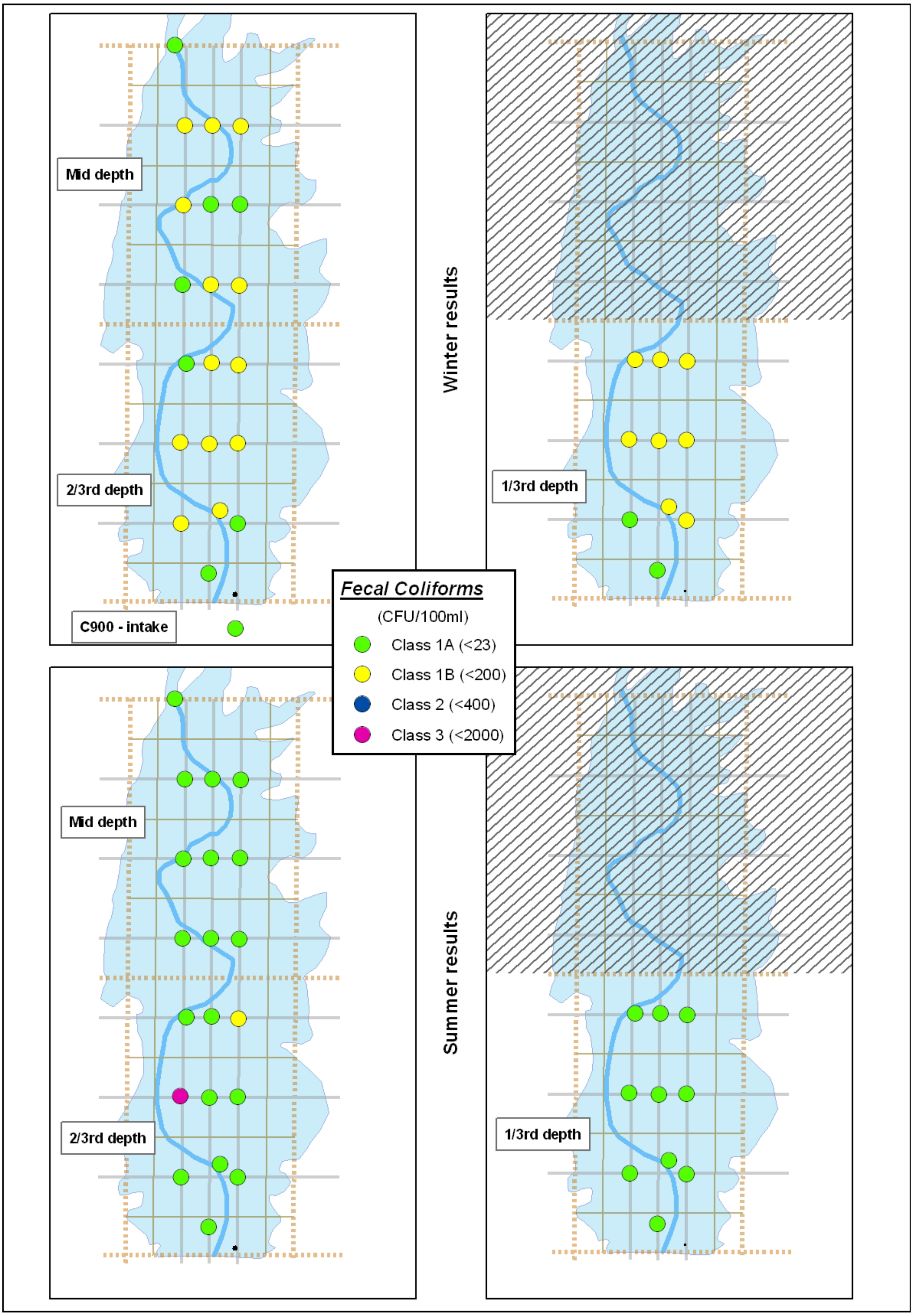


Figure 23. Analysis results of samples from the Qaraoun Lake (Fecal coliform) based on the classes of the proposed Lebanese MoE water quality guidelines for irrigation

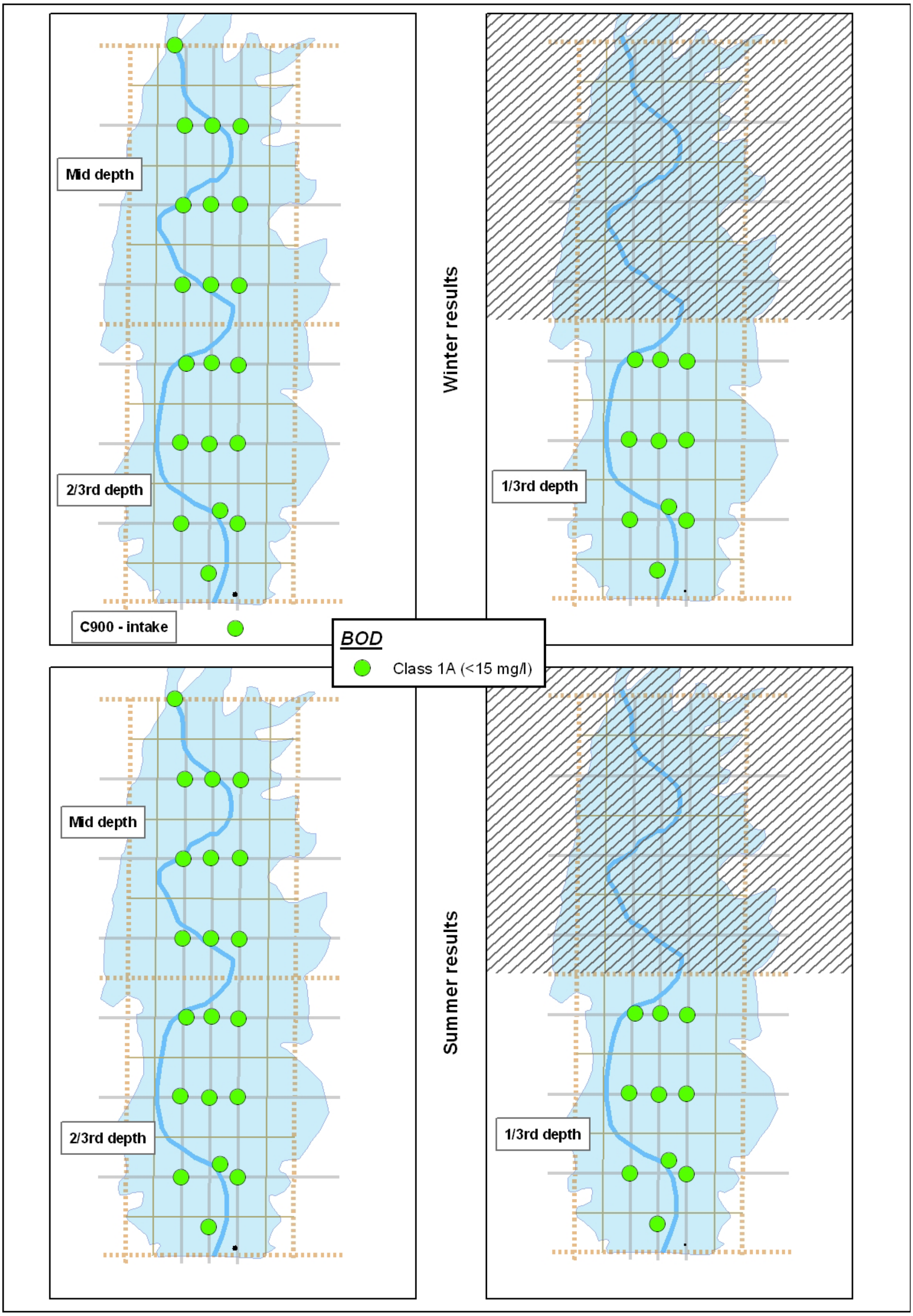


Figure 24. Analysis results of samples from the Qaraoun Lake (BOD) based on the classes of the proposed Lebanese MoE water quality guidelines for irrigation

2.2.3 Canal 900

Water samples from Canal 900 were collected from the canal (12 samples), the regulating reservoirs serving the three irrigation zones (3 samples), and irrigation outlets that are ultimately used by farmers for irrigation (5 samples). The analysis results for all the water samples from the canal are presented in Appendix H. When compared with the Lebanese MoE drinking water quality standards for domestic use, total and fecal coliforms levels in 20 and 15, respectively, of the 20 water samples collected exceed these standards. The total coliforms level ranges between 18 and 2400 CFU/100ml, with an average value of 550 CFU/100ml. On the other hand, fecal coliforms level ranges between 0 and 1200 CFU/100ml, with an average of 241 CFU/100ml. Ammonia levels in 19 of the 20 samples exceed the standard of 0.05 mg/l, values ranged between 0.01 and 1.1 mg/l, with an average of 0.49. Values for all other indicators were within acceptable limits, and consistent with the lake water quality.

As compared to the the reclaimed wastewater guidelines for irrigation of the Lebanese Ministry of Environment, fecal coliforms in 5 samples out of the 20 exceeded the threshold set for irrigation classes 1A, 1B, and 2 proposed by the guidelines, but not exceeding the threshold set for class 3 (Figure 26). On the other hand, all samples were within the BOD thresholds for all classes (Figure 27). As such, the overall water quality in the canal at the time of sampling is only acceptable for irrigation under the proposed class 3, access control with 250 meter set-back from dwelling units.

Eleven out of the 20 sampled locations from Canal 900 were also sampled during the winter sampling survey. When compared to each other, the average fecal coliform level in summer dropped from 710 to 456 CFU/100ml, while that for total coliform increased from 31 to 194 CFU/100ml (Figure 25). On the other hand, the average ammonia level (not shown on figure) increased from 0.32 to 0.6 mg/l. Conversely, average nitrates level decreased from 20.7 to 20.3 mg/l. Except for total coliforms such pattern is consistent with that observed for lake water samples.

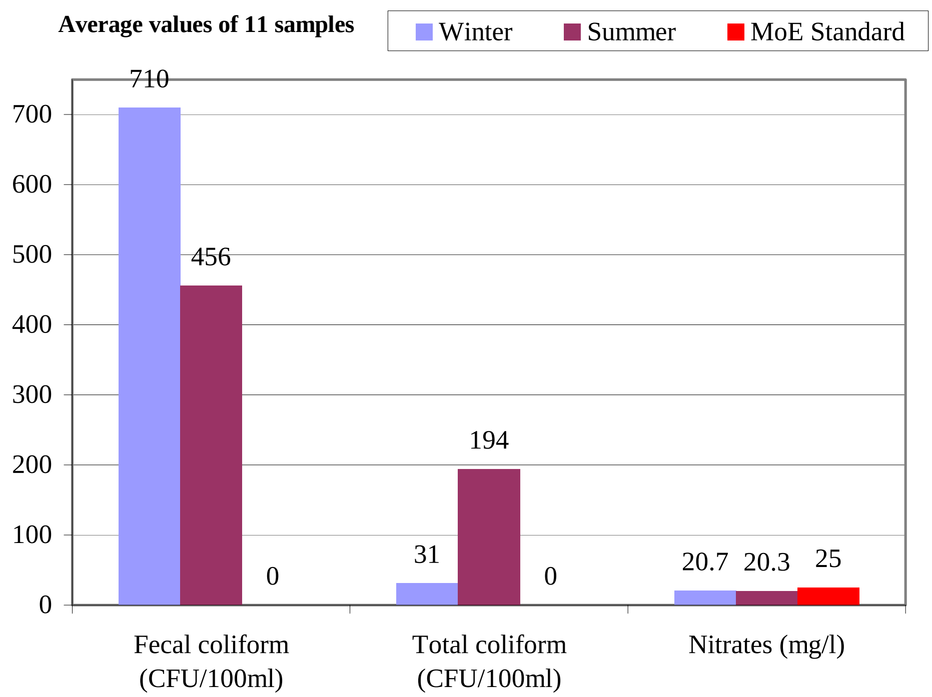


Figure 25. Comparison between winter and summer average results of FC, TC, and Nitrates for Canal 900 water samples

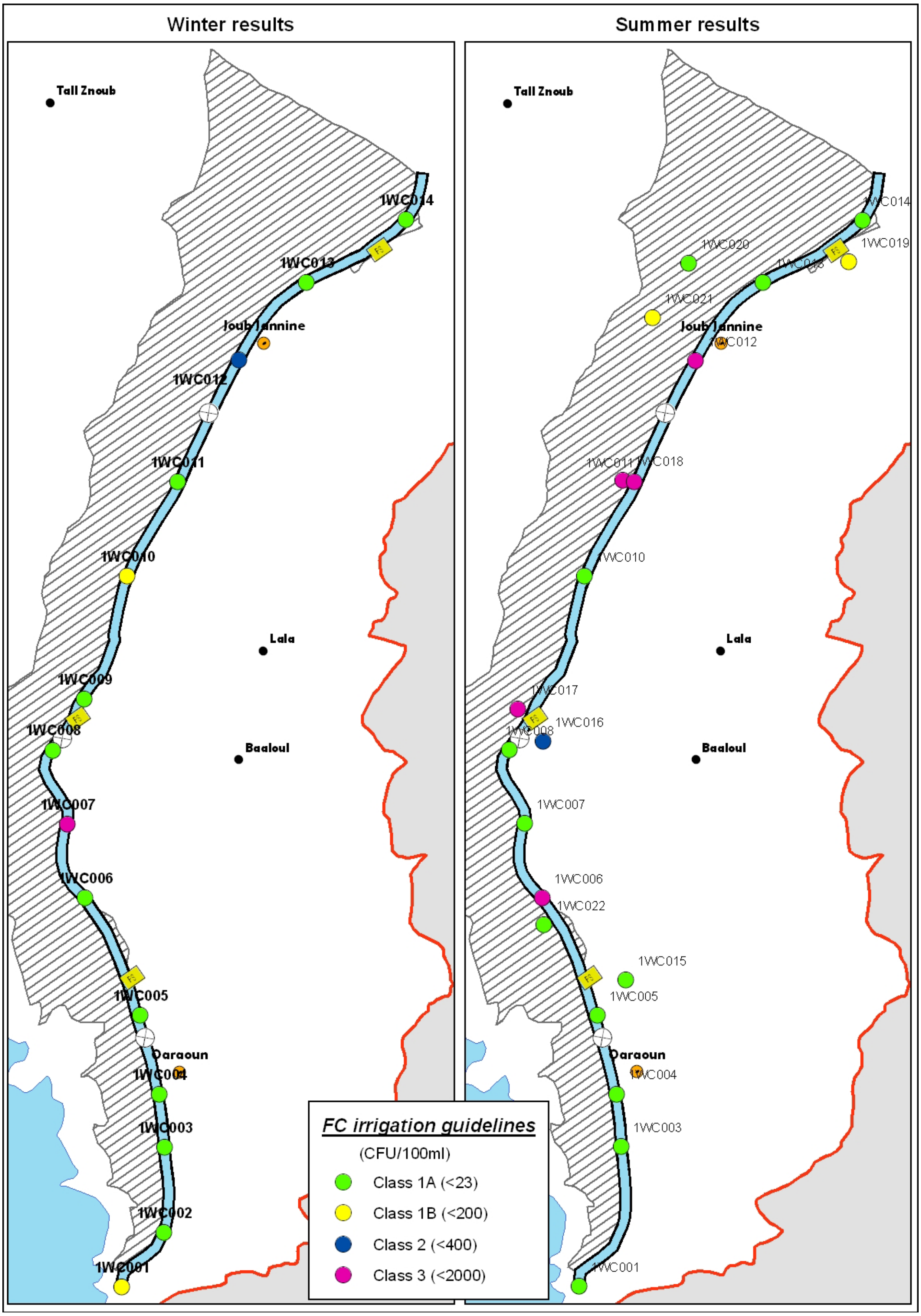


Figure 26. Analysis results for samples collected from Canal 900 (Fecal coliforms)

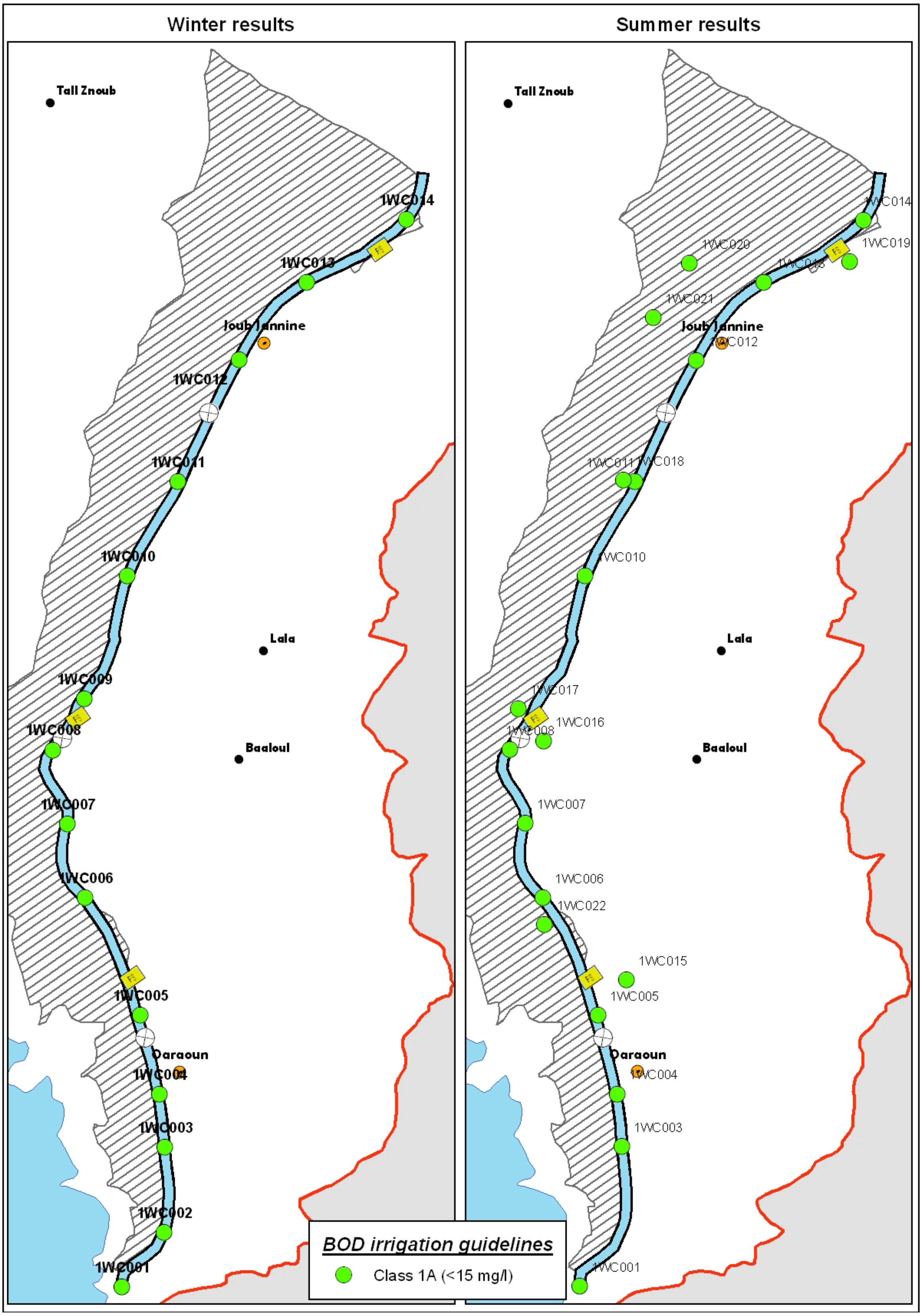


Figure 27. Analysis results for samples collected from Canal 900 (BOD)

2.2.4 Groundwater

Water samples were collected from sixty groundwater wells throughout the Upper Litani River Basin. The analysis results for all groundwater samples are presented in Appendix H. In general, from a statistical standpoint, the results of the groundwater sample analysis were similar to those obtained during the winter campaign. Pesticides and heavy metals were sampled and analyzed in 10 wells. Pesticides, namely organo-chlorines and organo-phosphates, were below the detection limits in all samples. (organochlorines < 0.005 mg/L; organophosphates < 0.15 mg/L). This can be attributed to 1) the biodegradability of these pesticides in the upper root zone thus not allowing them to reach the groundwater, and the relatively thick cover of the Quaternary-Neogene alluviums providing a deep vadoze zone of approximately 70 to 100 m before reaching the water table. Yet, the suitability of the groundwater for drinking, based on the pesticide analysis results, cannot be concluded as the European Standards require that, for drinking water, the maximum concentration for any pesticide should not exceed 0.0001 mg/L and the sum of the concentration of all pesticides should not exceed 0.0005 mg/L, which is lower than the detection limit of the AUB laboratory analytical equipment (0.005 mg/L). With respect to all the tested heavy metals, including Nickel, Copper, Lead, Mercury, Cadmium, Chromium, and Zinc, while some were detected, as compared to the non-detectable levels in all samples during winter, yet the levels were significantly below the MoE drinking water standards and the long-term threshold established by USEPA. This reflects a limited impact of industries on groundwater quality in the area during both the winter and summer season.

Total and fecal coliform levels exceeded the MoE drinking water standards in 78 and 35 percent of the sampled wells, respectively (Figure 28). High total and fecal coliform levels can be attributed to wastewater discharge practices in the area, including non-maintained septic tanks and open discharges. As for nitrate levels, they exceeded the MoE drinking water standards in 70 percent of the sampled wells. The unpolluted boreholes are located at the border of the Bekaa valley (Figure 29). These unpolluted boreholes are fed from the water Barouk/Sannine aquifers before it gets polluted by the anthropogenic activity in Bekaa. High nitrate levels are mostly attributed to common agricultural practices and the heavy application of fertilizers which accumulate in the soil during the summer season and are flushed down to the groundwater during the rainy winter season. Nitrates may also be the by-product of transformed nitrogenous compounds (in sewage, industrial and packing house wastes, drainage from livestock feeding areas and farm manures) that reach the groundwater. Conversely, phosphate reacts with soil constituents to form insoluble compounds that are immobile in soils and consequently poses less threat to groundwater. As such, phosphate levels exceeded the MoE drinking water standards in only 3 percent of the sampled wells (Figure 30). High levels of nitrates and fecal coliforms in drinking water are associated with health risks, such as the blue baby syndrome (methemoglobinemia) in the case of nitrates and gastrointestinal diseases in the case of fecal coliform (i.e. diarrhea, typhoids).

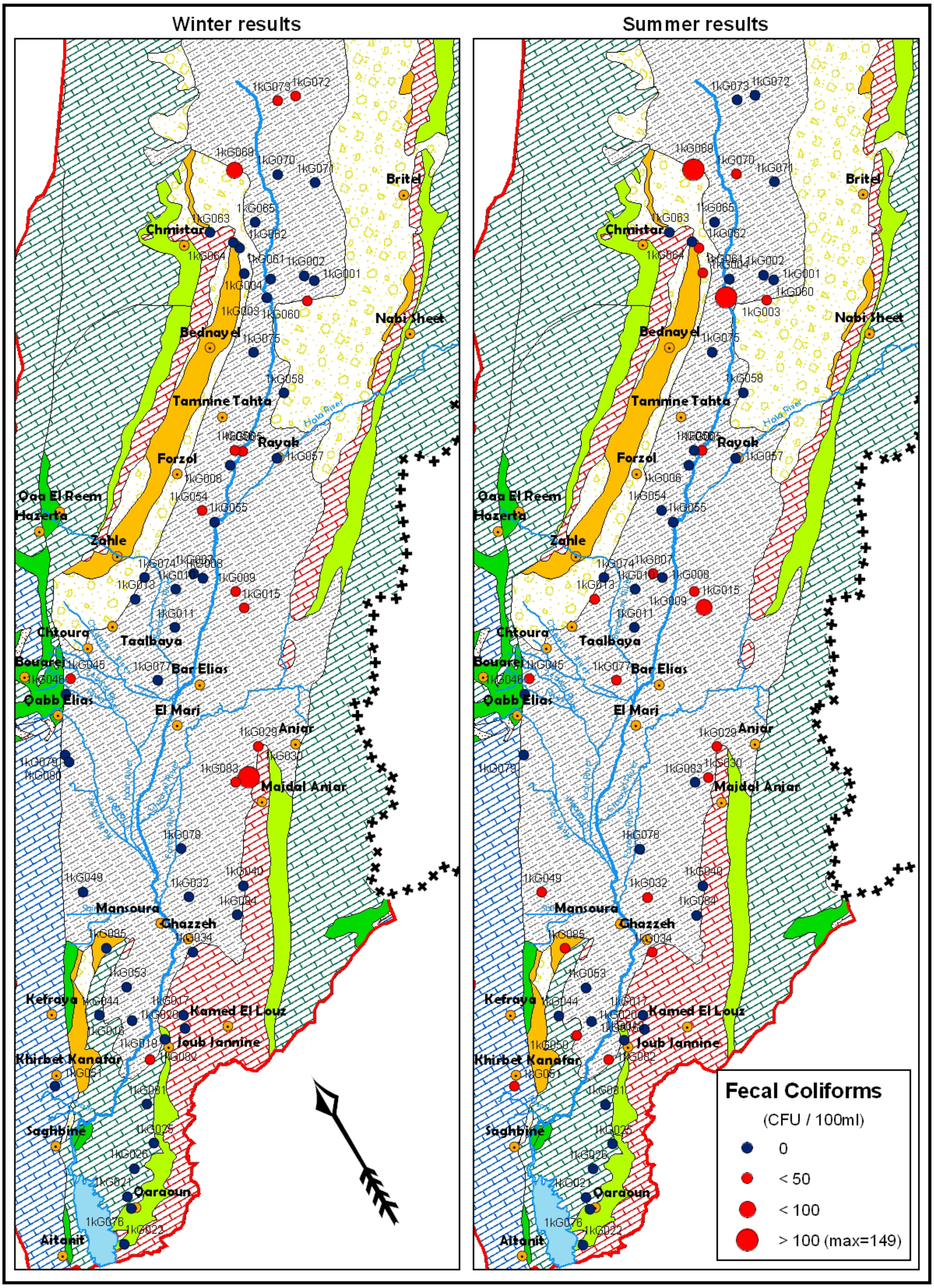


Figure 28. Analysis results for groundwater samples in the Upper Litani River Basin (Fecal Coliform)

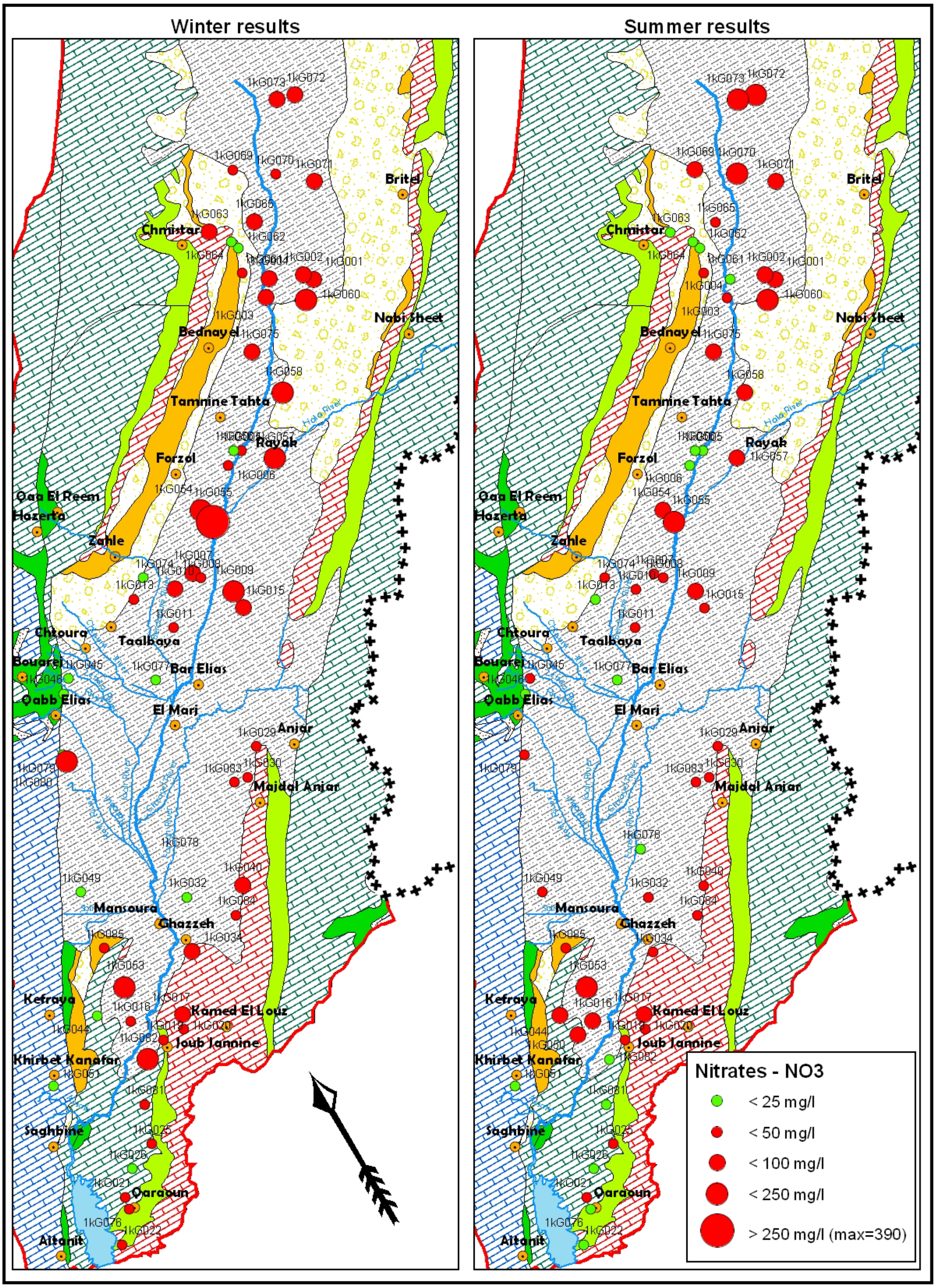


Figure 29. Analysis results for groundwater samples in the Upper Litani River Basin (Nitrates)

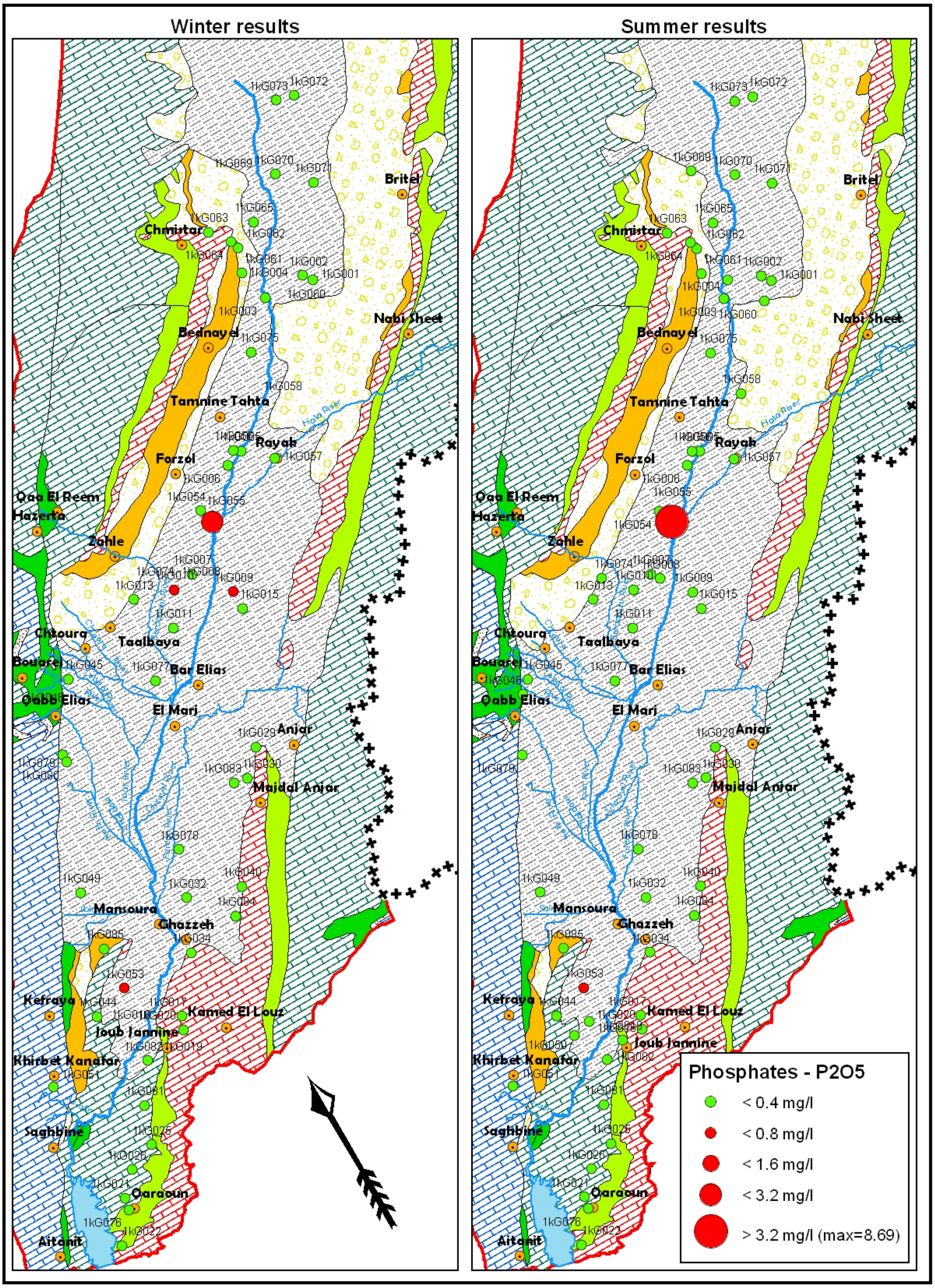


Figure 30. Analysis results for groundwater samples in the Upper Litani River Basin (Phosphates)

When compared to the winter results (Figure 31), the average phosphate levels increased, which may be attributed to a significant increase of concentration in one location, which already showed exceptional values during winter campaign. Additional site investigations are necessary to spot out the reason for this local source of pollution. For nitrates and sulfates the average value dropped from 58 mg/L to 48 mg/L and 37 mg/L to 30 mg/L respectively, but both species show similar statistical distribution between winter and summer, hence a seasonal variation couldn't be identified. Yet, the lower levels in summer may be attributed to the accumulation of these species in the soil and the absence of rain to flush them into the underlying groundwater aquifer. As for the fecal and total coliform levels, the average values show a significant increase. This trend is normal and is due to temperature increase on the surface, which stimulates the development of bacteria as well.

Table 5. Comparison between winter and summer maximum and average results and percentage exceedance of standards

Parameter	*Maximum*		*Average*		*Percent exceeding MoE Standards*	
	Winter	*Summer*	*Winter*	*Summer*	*Winter*	*Summer*
Phosphate (mg/L)	3.10	11.70	0.16	0.32	7%	3%
Nitrate (mg/L)	318.00	171.00	58.39	48.15	75%	70%
Sulfate	250.00	205.00	37.45	30.45	33%	35%
Feacal Coliforms	105	149	4	8	23%	35%
Total Coliforms	255	400	17	43	63%	78%

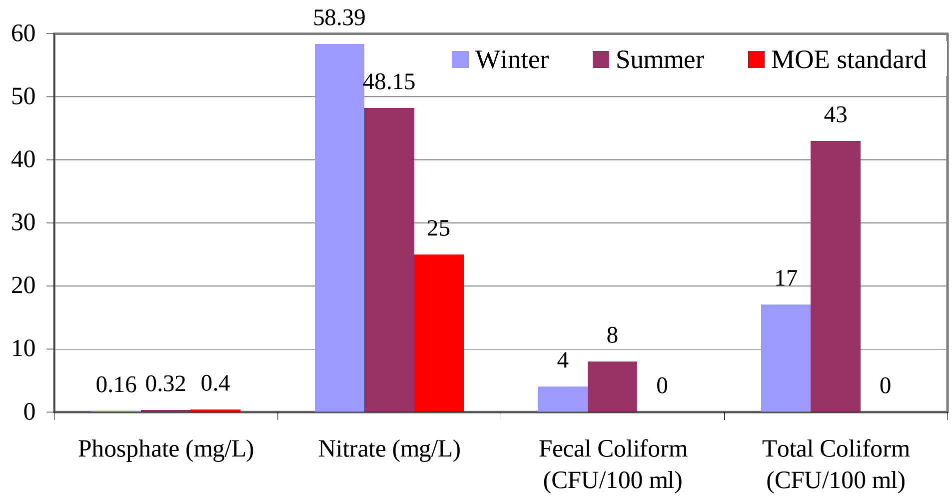


Figure 31. Comparison between winter and summer average results of Phosphates, Nitrates, FC, and TC, for groundwater samples

2.2.5 Water samples comparative assessment

River samples exhibited high levels of bacteriological contamination (TC, FC, BOD and COD) for the summer sampling round (Table 6). The levels in this round increased in comparison with those meausred in the winter season due primarily to the low dilution factor and the relatively higher wastewater generation rate in the summer season. Similarly, the highest nitrate levels were recorded in summer groundwater samples in comparison with the winter samples due to the increased application rates of agrochemicals during this season. On the other hand, summer Lake water samples exhibited a decrease in concentrations in comparisn with winter samples because a limited quantity of contaminant-laden water reaches the Lake due to the excessive pumping and utilization of river water upstream of the Lake.

Table 6. General comparison of water analysis results for various sample types for winter and summer sampling rounds

Indicator	*Survey round*	*River (94 samples including springs and sources)*			*Lake (30 samples)*			*Canal 900 (13 samples)*			*Groundwater (60 samples)*			*Drinking water standard*			*Reclaimed WW for irrigation*
														MoE-Lebanon		*USEPA*	
		Min.	*Avg.*[3]	*Max.*	*Min.*	*Avg.*[3]	*Max.*	*Min.*	*Avg.*[3]	*Max.*	*Min.*	*Avg.*[3]	*Max.*	*GV*[1] *(20 °C)*	*GV*[1] *(25 °C)*	*GV/MAL*[2]	*MoE guidelines*
pH (pH units)	W	6.8	7.59	8.18	6.82	7.58	7.78	7.07	7.50	7.99	6.41	6.85	7.5	6.5-8.5	6.5-8.5	6.5-8.5	
	S	6.57	7.1	7.68	6.5	7	7.5	6.7	7.09	7.46	6.54	6.9	7.22				
Temperature (°C)	W	4.1	12.39	17.7	11.3	12.52	16	12.9	16.75	21.2	11.6	17.26	20.1	12	NA[6]	NA	
	S	11.7	20.1	24.6	16.5	20.7	24.8	15.8	20.63	25.7	18.4	22	33.3				
DO (mg/l O_2)	W	3.95	7.94	9.73	6.45	7.59	8.68	3.2	9.15	15.44	-	-	-	NA	NA	NA	
	S	0.43	3.93	7.83	1.3	3.3	7.7	2	4.84	7.76	-	-	-				
TDS (mg/l)	W	114	202.2	415	211	226.8	239	222	238.4	257	-	-	-	400[7]	500[8]	500[8]	
	S	88.2	290.9	706	120	160	196	148	191	208	-	-	-				
NH_4[9] (mg/l)	W	<0.01	1.12	11.01	0.52	0.62	0.7	0.11	0.30	0.47	-	-	-	0.05	NA	NA	
	S	<0.01	13	127	<0.02	0.3	1	<0.01	0.49	1.1	-	-	-				
P_2O_5[10] (mg/l)	W	0.01	0.31	2.01	0.19	0.22	0.33	0.01	0.21	0.4	<0.01	0.12	2.3	0.4	NA	NA	
	S	0.01	8.73	146.4	0.01	0.13	0.35	0.01	0.18	0.4	0.01	0.2	8.69				
NO_3^- (mg/l)	W	<1.0	13.57	49.7	16.2	27.9	34.1	16.8	20.7	25.1	1	60.32	318	25	10 (as N)	10 (as N)	
	S	3	13.5	62	16.1	21.7	31.2	11.2	19.75	24.4	2.8	48	170.8				
SO_4^{2-} (mg/l)	W	<7	19.65	115	34	39	43	32	36.8	44	7	39.08	250	25	250	250	
	S	4	21.26	225	25	29.3	33	27	30.45	33	7	31	205				
BOD (mg/l)	W	0	6.57	45	<2	2.1	3	<2	3.7	2.1	-	-	-	NA	NA	NA	10-45
	S	<2	48.5	624	<2	2.57	4	<2	<2	<2	-	-	-				
COD (mg/l)	W	0	14.73	116	<2	3.87	10	<2	4	15	-	-	-	NA	NA	NA	
	S	2	85.75	950	3	10	65	2	6.2	15	-	-	-				
FC (CFU[11]/100,ml)	W	0	20,122	120,000	6	39	196	0	27	216	0	4	105	0	0	0	5-2,000
	S	0	223,488	1,500,000	0	17	450	0	241	1200	0	8	149				
TC (CFU[11]/100,ml)	W	0	22,216	120,000	23	64	208	12	617	2900	0	18	255	0	0	0	
	S	2	308,407	1,500,000	0	23	450	18	550	2400	0	43	400				

[1] GV: Guideline value
[2] MAL: Maximum admissible level ; USEPA: US Environmental Protection Agency
[3] All values reported < a certain value are set equal to that value when calculating the average
[4] W: Winter sampling round, based on 94 river samples including springs and sources
[5] S: Summer sampling round, based on 76 river samples including springs and sources
[6] NA: Not applicable
[7] reference temperature at 20°C
[8] reference temperature at 25°C
[9] Initial value reported is NH_3 , for comparison a conversion factor of 1.0588 was used ($NH_4 = NH_3*1.0588$)
[10] Initial value reported is o-PO_4^{3-}, for comparison a conversion factor of 0.743 was used (P_2O_5 = o-PO_4^{3-} *0.743)
[11] CFU: colony forming unit

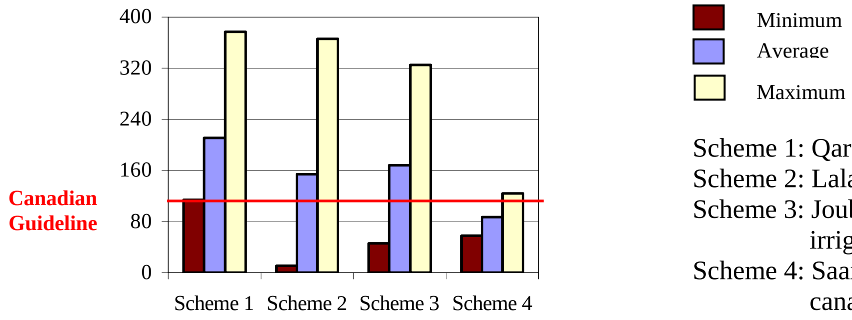
Highlighted values exceed standards

2.2.6 Soil

Soil samples collected from the three zones of the Canal 900 irrigation schemes (1-Qaraoun area, 2-Lala area, and 3-Joub Jannine-Kamed El Laouz area), and from Saaide area near the Yammounneh irrigation canal (scheme 4) were analysed in comparison to the Canadian environmental quality guidelines (Table 7). The comparison indicated that chromium levels in soil samples from schemes 1, 2 and 3 exceeded the guideline for agricultural use (64 mg/Kg) by more than two to three folds (Figure 32), with average concentrations of 211, 154, and 167 mg/kg in schemes 1, 2, and 3, respectively. Likewise, samples collected from scheme 4 (irrigated from the Yammouneh canal and groundwater wells) exhibited chromium levels ranging between 57 and 123 mg/kg with an average of 87 mg/kg, thus exceeding the guideline of 64 mg/Kg. Similarly, cadmium levels detected in samples collected from schemes 1, 2, and 3 were above the Canadian guideline (1.4 mg/kg), with average concentrations of 2.83, 4.5, and 3.14 mg/kg for schemes 1, 2, and 3, respectively, while levels detected in samples from scheme 4 were within acceptable limits (average, 0.7 mg/kg). As for copper, levels below the Canadian guideline (63 mg/kg), were detected in almost all samples from the four schemes, except in scheme 2 where 4 samples exhibited levels ranging between 64 and 90 mg/kg. The association of the recorded metal levels in soil samples exclusively to the quality of irrigation water is relatively weak because the metals were not detected in the Lake water samples during the winter and summer. Accumulation process over several irrigation cycles may explain some of the oberved high levels. Moreover, natural background and traces in agrochemicals that may be in use in the area represent another potential source, particularly with the absence of industrial activities in the vicinity of Canal 900. The analysis results of all soil samples are tabulated in Appendix H.

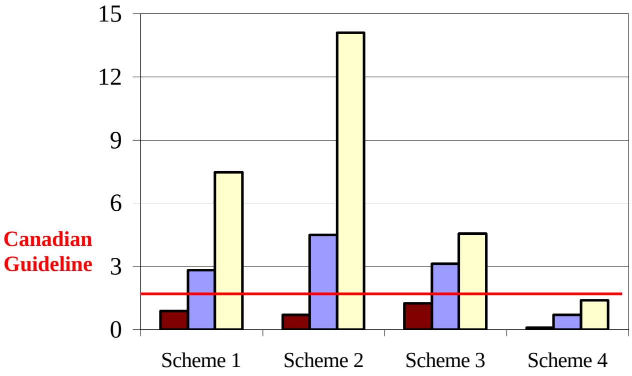
Table 7. Canadian environmental quality guidelines for soil (NGSO, 2005)

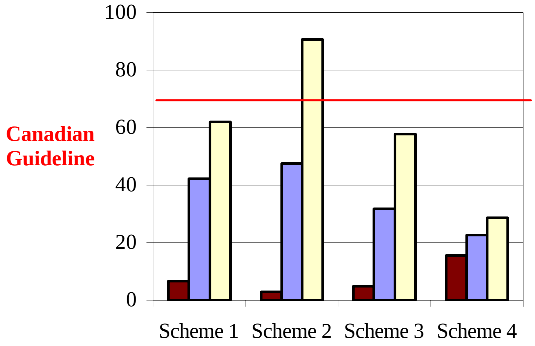
Parameter	*Agriculture use*
Chromium (mg/kg)	64
Copper (mg/kg)	63
Cadmium (mg/kg)	1.4



Scheme 1: Qaraoun area, irrigated from Canal 900
Scheme 2: Lala area, irrigated from Canal 900
Scheme 3: Joub Jannine-Kamed El Laouz area, irrigated from Canal 900
Scheme 4: Saaide area, irrigated from Yammouneh canal and ground water wells

Chromium (mg/Kg)





Cadmium (mg/kg) Copper (mg/kg)

Figure 32. Heavy metal analysis results of soil samples

Winter and summer levels of chromium and cadmium detected in soil samples are compared in Table 8. Chromium summer results have shown a spatial variability within the one order of magnitude for samples collected from the three schemes irrigated by water from Canal 900. For instance, the average summer levels of chromium in schemes 1, 2, and 3 are 261, 69, and 164 mg/Kg, respectively. The winter results exhibited less spatial variability whereby the average chromium levels ranged between 177 and 192 mg/Kg. The cadmium levels showed a relatively lower spatial variability among samples collected from the three schemes (1, 2, and 3) in both the winter amd summer sampling rounds. For example, the average levels in schemes 1, 2, and 3 varied between 2.44, 1.46, and 3.09 mg/Kg for winter, and 3.65, 1.08, and 3.0 mg/Kg for summer, for the three schemes respectively.

Table 8. Winter and summer results for chromium and cadmium in soil samples

Irrigation Scheme	*Sample*[a]	*Chromium (mg/Kg)*		*Cadmium (mg/Kg)*	
		Winter	*Summer*	*Winter*	*Summer*
1	001	84.15	195.79	1.51	2.40
	002	282.21	150.73	1.42	1.94
	003	122.51	377.20	4.38	3.30
	004	254.37	371.25	2.04	7.46
	005	145.35	214.49	2.87	3.16
	Min.	*84.15*	*150.73*	*1.42*	*1.94*
	Avg.	*177.72*	*261.89*	*2.44*	*3.65*
	Max.	*282.21*	*377.20*	*4.38*	*7.46*
2	006	69.64	131.48	0.81	1.17
	007	159.7	55.56	0.97	0.69
	008	301.98	33.41	2.89	1.05
	009	236.79	56.24	1.15	1.41
	Min.	*69.64*	*33.41*	*0.81*	*0.69*
	Avg.	*192.03*	*69.17*	*1.46*	*1.08*
	Max.	*301.98*	*131.48*	*2.89*	*1.41*
3	011	202.48	46.06	2.15	1.25
	012	179.59	325.00	1.95	4.54
	013	171.95	259.92	5.16	2.67
	014	182.85	81.16	1.18	3.90
	015	226.57	71.07	5.02	2.64
	Min.	*171.95*	*46.06*	*1.18*	*1.25*
	Avg.	*192.69*	*156.64*	*3.09*	*3.00*
	Max.	*226.57*	*325.00*	*5.16*	*4.54*
4	016	16.574	57.68	0.002	0.16
	017	13.363	60.80	0.002	0.10
	018	16.461	91.71	0.002	1.39
	019	14.113	101.36	0.002	1.00
	Min.	*13.36*	*57.68*	*0.002*	*0.10*
	Avg.	*15.13*	*77.89*	*0.002*	*0.66*
	Max.	*16.57*	*101.36*	*0.002*	*1.39*
	Canadian Guideline	*64*		*1.4*	

[a] Original sample ID.: 1WO--- for winter sampling round, and 2WO--- for summer sampling round

2.2.7 Crop samples

Crop samples were analyzed for copper, cadmium and chromium. Copper levels ranged between 0.4 and 2.73 mg/Kg, with an average of 0.98 mg/Kg. Similarly, cadmium and chromium were detected in crop samples with levels ranging between 0.04 and 0.98 mg/Kg, and 0.11 and 17.63 mg/Kg, respectively; with an average of 0.26 mg/Kg for cadmium and 3.9 mg/Kg for chromium. The results of crop samples analysis provide a backgound of copper in crops for future comparison and impact assessment of algae control with copper sulfate. Similarly, the detected levels of Cadmium and Chromium can be used in future exposure assessment in a long term monitoring program.

2.2.8 Fish

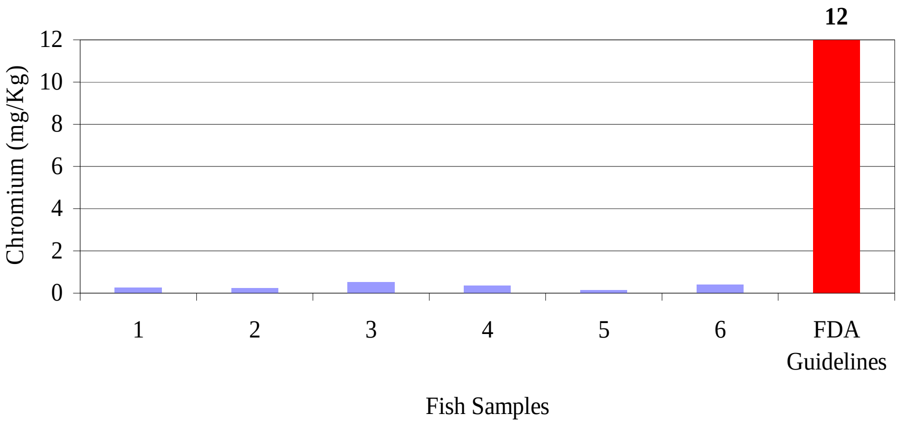
Concentrations of heavy metals in fish may be indicative of the degree of probable bioaccumulation and biomagnification of the levels of heavy metals in the Qaraoun water, whereby the latter were insignificant and below detectable levels. The fish collected from the Qaroun lake were anlyzed for the presence of selected heavy metals - chromium, cadmium and copper. A total of six tissue samples, one skeleton sample, one gill sample, and one composite sample were analyzed. While analysis on tissue samples was successful, it could not be replicated. The analysis of the other samples (skeleton, gill, and composite) could not be ascertained, and therefore it is not reported (Table 9). Chromium levels ranged between 0.14 and 0.527 mg/kg (average = 0.317 mg/kg) which are below the Food and Drug Administration (FDA) Levels for Toxic Elements in Fish (12 mg/Kg) (Figure 33). On the contratry, Cadmium levels ranged between 0.17 and 8.13 mg/kg (average = 1.95 mg/kg) exceeding the FDA guideline of 3 mg/Kg in one sample. Copper levels ranged between 1.52 and 3.01 mg/Kg with an average of 1.95 mg/Kg.

The chromium and cadmium levels detected in fish samples in the summer sampling, along with those detected in the winter sampling round, are compared in Figure 34. Chromium levels in all summer samples were slighly higher, with the average increasing from 0.05 mg/Kg in winter sampling to 0.32 mg/Kg in summer sampling. Such a difference is within the range of detection of the analyzing equipment and hence it is difficult to discuss the significance of these levels particularly that they are all below recommended guidelines. On the other hand, the average cadmium level decreased from 11.33 mg/kg in the winter sampling to 1.95 mg/kg in the summer sampling. One sample in the summer sampling round and two samples in the winter sampling round exceeded the recommended guidelines. Further monitoring of fish in the lake at increased frequency and total number of samples is highly desirable to be able to reach a statistically significant interpretation of potential exposure. University and other research institutions may play a role in conducting comprehensive fish monitoring program.

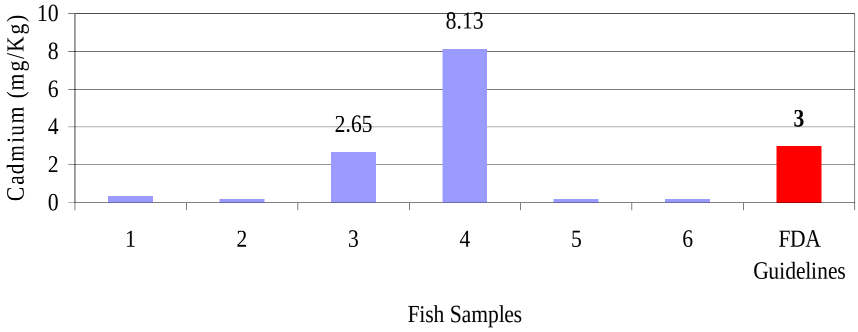
Table 9. Analysis results of fish samples from Lake Qaraoun

Fish	*Chromium (mg/Kg)*	*Cadmium (mg/Kg)*	*Copper (mg/Kg)*
1	0.253	0.340	3.0
2	0.237	0.174	2.193
3	0.527	2.653	1.72
4	0.347	8.131	1.523
5	0.140	0.198	1.60
6	0.399	0.198	1.645
7	NR*	NR	NR
8	NR	NR	NR
9	NR	NR	NR
Detection limit	0.002	0.125	-
FDA guideline	*12*	*3*	*Not applicable*

* NR: not reported, quality control check failed

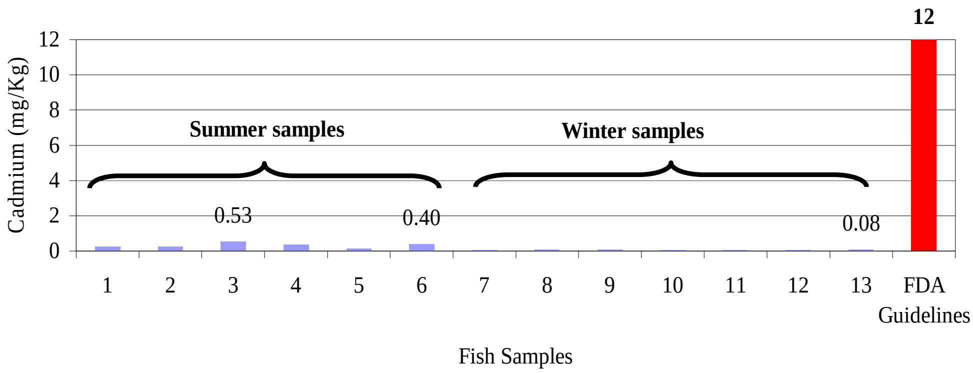


Chromium (mg/Kg)

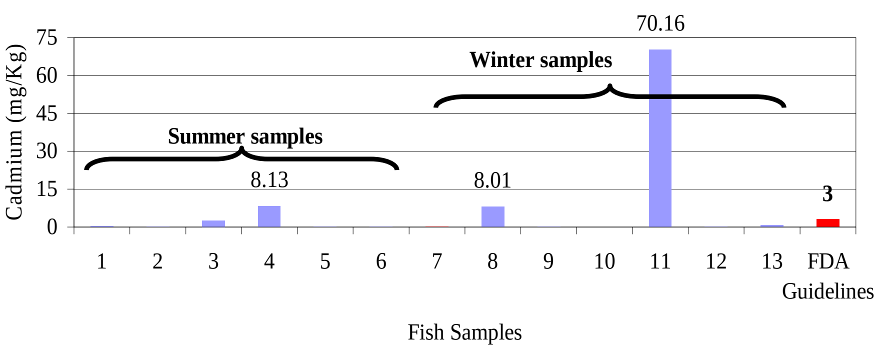


Cadmium (mg/Kg)

Figure 33. Analysis results of fish samples from Lake Qaraoun



Chromium (mg/Kg)



Cadmium (mg/Kg)

Figure 34. Comparison between winter and summer results for chromium and cadmium in fish samples from Lake Qaraoun

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Appendix A5	Daily sample log sheet for Environmental Engineering Research Center
Appendix A6	Daily sample log sheet for Environment Core Laboratory

Appendix A1. Reconnaissance log sheet for surface water samples

No.	*Sample Matrix*	*Field validated sample location description*				
		Code	*Photo ID*	*E (DD)* *N (DD)*	*Alt. (m)*	*Description/Remarks*
1				E N		
2				E N		
3				E N		
4				E N		
5				E N		
6				E N		
7				E N		
8				E N		
9				E N		

Appendix A2. Reconnaissance log sheet for groundwater samples

WELL DESCRIPTION FORM

Engineer name: _______________ **Date: ______________** **Time: ___________**

Well Code: _______________ **Well Depth: ________ m** **Geologic Formation Tapped: __________________________**

Well Location:

Name of Site	Town/City	District/Caza	Region/Mohafaza

GPS Coordinates:

N	
E	

Relative Position of Well:

Perpendicular Distance from Sea Coast	Elevation Above Sea Level (GPS)

Well Owners:

Public Sector	Name of Public Sector	Private Sector	Name of Private Sector

History of Well:

Date of Construction	Duration of Construction	Is Borehole Plumb?	Is Borehole Straight?

Type of Usage:

Human Consumption	Industrial Purposes	Agricultural Purposes	Monitoring Purposes

Pumping Rate and Well Yield:

Pumping Rate	Well Yield

Casing:

Casing Length	Casing Depth	Casing Material

Casing Diameter:

6”	8”	10”	12”	14”	16”	20”	24”	

Screen:

Screen Length	Screen Depth	Screen Material

Screen Diameter:

4”	6”	8”	10”	12”	14”	16”	17”	18”	21”	23”

Screen Properties:

Screen Type	Slot Size	% Open Area

Filter Pack:

Filter Pack Used	Filter Pack Depth	Gravel Pack Used	Gravel Pack Depth

Pump Size:

4”	5”	6”	8”	10”	12”	14”	16”	20”

Appendix A3. Surface sample log sheet

1. Sample code: ______________________

2. Sampling station: N ____________________ E __________________ Altitude __________m

3. Date: __________ **4. Time:** _____________

5. Weather conditions: ☐ Sunny ☐ Cloudy ☐ Windy ☐ Rainy

6. Photo IDs: ____

7. Site description:
____
____
____

8. Samples collected: ☐ Standard chemistry ☐ Heavy metals ☐ Microbiology ☐ Pesticide

9. Sample depth from surface: _______________ **m**

10. Problems encountered/ adaptations made during sampling: ______________________
____
____

11. Analysis undertaken on-site:

Variable	**Method used**	**Equipment name**	**Reading Value**
Temperature	____________	____________	____________°C
pH	____________	____________	____________
DO	____________	____________	____________

12. General remarks: ____
____
____

13. Collector:	Name ______________	Signature __________	Date __________
14. Data received by:	Name ______________	Signature __________	Date __________

Appendix A4. Groundwater sample log sheet

1. **Sample code:** ________________________
2. **Sampling station:** N ____________________ E ________________ Altitude __________m
3. **Date:** _________
4. **Time:** ____________
5. **Weather conditions:** ☐ Sunny ☐ Cloudy ☐ Windy ☐ Rainy
6. **Photo IDs:** ____
7. **Site description:** ____
____
____

8. **Samples collected:** ☐ Standard chemistry ☐ Heavy metals ☐ Microbiology ☐ Pesticides
9. **Depth to water table:** ______________ **m**
10. **Problems encountered/ adaptations made during sampling:** ________________________________
____
____

11. **Analysis undertaken on-site:**

Variable	**Method used**	**Equipment name**	**Reading Value**
Temperature	_________________	__________________	_________________°C
pH	_________________	__________________	_________________
DO	_________________	_________________	_________________

12. **General remarks:** ____
____
____

13. Collector:	Name ____________________	Signature ____________	Date ____________
14. Data received by:	Name ____________________	Signature ____________	Date ____________

Appendix A5. Daily sample log sheet for Environmental Engineering Research Center

Date: _________________

Samples presented by: __________________ ____________ **Signature**

Samples received at lab by:________________ ____________ **Signature** ________ **Time**

Total number of samples: ________________

Sample ID	***Matrix***	***No. of vials***	***Parameters to be Tested***		
			☐ Total coliform ☐ Fecal coliform	☐ Nitrates ☐ Phosphates ☐ Sulfates	☐ TDS ☐ COD ☐ DO ☐ Ammonia ☐ BOD
			☐ Total coliform ☐ Fecal coliform	☐ Nitrates ☐ Phosphates ☐ Sulfates	☐ TDS ☐ COD ☐ DO ☐ Ammonia ☐ BOD
			☐ Total coliform ☐ Fecal coliform	☐ Nitrates ☐ Phosphates ☐ Sulfates	☐ TDS ☐ COD ☐ DO ☐ Ammonia ☐ BOD
			☐ Total coliform ☐ Fecal coliform	☐ Nitrates ☐ Phosphates ☐ Sulfates	☐ TDS ☐ COD ☐ DO ☐ Ammonia ☐ BOD
			☐ Total coliform ☐ Fecal coliform	☐ Nitrates ☐ Phosphates ☐ Sulfates	☐ TDS ☐ COD ☐ DO ☐ Ammonia ☐ BOD
			☐ Total coliform ☐ Fecal coliform	☐ Nitrates ☐ Phosphates ☐ Sulfates	☐ TDS ☐ COD ☐ DO ☐ Ammonia ☐ BOD
			☐ Total coliform ☐ Fecal coliform	☐ Nitrates ☐ Phosphates ☐ Sulfates	☐ TDS ☐ COD ☐ DO ☐ Ammonia ☐ BOD
			☐ Total coliform ☐ Fecal coliform		

Appendix A6. Daily sample log sheet for Environment Core Laboratory

Date: ________________

Samples presented by: __________________ **____________**
Signature

Samples received at lab by:________________ **____________** **_________**
Signature **Time**

Total number of samples: ________________

Sample ID	*Matrix*	*No. of vials*	*Parameters to be Tested*			
			☐ Lead ☐ Mercury ☐ Cadmium ☐ Chromium	☐ Nickel ☐ Copper ☐ Zinc	☐ Organo-phosphorous ☐ Organochlorine	☐ Nitrates ☐ Phosphates
			☐ Lead ☐ Mercury ☐ Cadmium ☐ Chromium	☐ Nickel ☐ Copper ☐ Zinc	☐ Organo-phosphorous ☐ Organochlorine	☐ Nitrate ☐ Phosphate
			☐ Lead ☐ Mercury ☐ Cadmium ☐ Chromium	☐ Nickel ☐ Copper ☐ Zinc	☐ Organo-phosphorous ☐ Organochlorine	☐ Nitrate ☐ Phosphate
			☐ Lead ☐ Mercury ☐ Cadmium ☐ Chromium	☐ Nickel ☐ Copper ☐ Zinc	☐ Organo-phosphorous ☐ Organochlorine	☐ Nitrate ☐ Phosphate
			☐ Lead ☐ Mercury ☐ Cadmium ☐ Chromium	☐ Nickel ☐ Copper ☐ Zinc	☐ Organo-phosphorous ☐ Organochlorine	☐ Nitrate ☐ Phosphate
			☐ Lead ☐ Mercury ☐ Cadmium ☐ Chromium	☐ Nickel ☐ Copper ☐ Zinc	☐ Organo-phosphorous ☐ Organochlorine	☐ Nitrate ☐ Phosphate

Appendix B. List of documented sources of pollution

Code	*E*	*N*	*Village*	*Category*	*Description*
1WF001	35.70547	33.55442	Qaroun	Industry	Olive oil Press
1WF002	35.70962	33.56942	Saghbine	Dumpsite	Waste Disposal
1WF003	35.73475	33.63305	Khirbet Kanafar	Dumpsite	Waste Disposal
1WF020	35.81929	33.68056	Ghazze	Dumpsite	Waste Disposal
1WF023	35.79802	33.66315	Mansoura	Dumpsite	Waste Disposal
1WF031	35.90326	33.72433	Anjar	Industry	Sugar factory
1WF043	35.80665	33.76289	Mazrait Bmohray	Industry	SICOMO factory
1WF046	35.82222	33.79753	Kabelias	Industry	Arak Touma factory
1WF064	35.83812	33.81501	Chtaura	Industry	Food Processing
1WF072	35.83907	33.82462	Jdita	Industry	Milk Processing
1WF076	35.85117	33.80964	Chtaura	Industry	Brick processing
1WF089	35.87793	33.87895	Qaa el Rim	Industry	Tissue Paper processing
1WF092	35.87777	33.87751	Qaa el Rim	Industry	Cardboard
1WF102	35.91291	33.82824	Zahle	Industry	Dairy Slaughter House
1WF110	35.91291	33.80056	Zahle	Landfill	Solid Waste Management
1WF165	35.97766	33.85885	Ablah	Industry	Tanmiya
1WF182	35.94446	33.85573	Ferzol	Industry	Potato Processing
1WI044	35.80958	33.76254	Mazrait Bmohray	Industrial discharge	SICOMO factory
1WR018	35.78078	33.64182	Jib Jannine	Dumpsite	Waste Disposal
1WR019	35.81932	33.66961	Ghazze	Waste water discharge	Into Litani River
1WR022	35.81790	33.67788	Mansoura	Waste water discharge	Into Litani River
1WR025	35.84616	33.73072	Houch el Harimeh	Dumpsite	Waste Disposal
1WR026	35.87199	33.74189	Houch el Harimeh	Industrial discharge	Sugar factory
1WR042	35.81607	33.74792	Tal el Akhdar	Waste water discharge	Normal Flow point
1WR055	35.83371	33.80450	Mekse	Waste water discharge	Into Mekse river
1WR056	35.85050	33.78524	Qabelias	Waste water discharge	Into Mekse river
1WR060	35.83704	33.81523	Mekse	Waste water discharge	Into earthen canal
1WR065	35.83785	33.81468	Chtaura	Industrial discharge	Into concrete channel
1WR068	35.84204	33.81401	Jdita	Waste water discharge	Into Jdita river
1WR069	35.85229	33.81564	Chtaura	Waste water discharge	Normal Flow point
1WR077	35.85312	33.80639	Chtaura	Industrial discharge	Brick Processing
1WR084	35.86183	33.82106	Taalabaya	Waste water discharge	Into Jalala river
1WR087	35.86477	33.80455	Taanayel	Waste water discharge	Normal Flow point
1WR091	35.87607	33.87830	Qaa el Rim	Industrial discharge	Pulp processing
1WR103	35.90239	33.82085	Zahle	Waste water discharge	Into Berdouni
1WR106	35.89396	33.81227	Saadnayel	Waste water discharge	Into Berdouni
1WR107	35.89151	33.80783	Saadnayel	Waste water discharge	Into Berdouni
1WR108	35.89216	33.79505	Taalbaya	Waste water discharge	Into Berdouni
1WR109	35.93982	33.81418	Zahle	Waste water discharge	Normal Flow point
1WR111	35.91618	33.79552	Zahle	Landfill runoff	Into Litani River
1WR112	35.91793	33.79706	Zahle	Waste water discharge	Into Litani River
1WR117	35.89359	33.75999	Barelias	Waste water discharge	Into Ghzayyel river
1WR118	35.90479	33.75954	Barelias	Waste water discharge	Into Ghzayyel river
1WR128	35.98914	33.86356	Ablah	Waste water discharge	Into Litani River
1WR130	35.99906	33.86830	Temnin Tahta	Waste water discharge	Into Litani River
1WR131	36.01956	33.89011	Bidnayel	Waste water discharge	Into Litani River
1WR132	36.02360	33.88513	Bidnayel	Waste water discharge	Into Litani River

Code	*E*	*N*	*Village*	*Category*	*Description*
1WR133	36.02444	33.88667	Qsarnaba	Dumpsite	-
1WR134	36.02736	33.88805	Houch el Ghanam	Waste water discharge	Into Litani River
1WR136	36.03586	33.90154	Bidnayel	Waste water discharge	Into Litani River
1WR137	36.03634	33.90200	Chehaymiye	Waste water discharge	Into Litani River
1WR140	36.06083	33.94364	Houch Bai	Waste water discharge	Into Litani River
1WR141	36.07942	33.97029	Hadath Baalbeck	Waste water discharge	Into Litani River
1WR142	36.07983	33.97468	Hadath Baalbeck	Industrial discharge	Into Litani River
1WR143	36.07992	33.96872	Hadath Baalbeck	Waste water discharge	Into Litani River
1WR144	36.07958	33.96608	Hadath Baalbeck	Waste water discharge	Into Litani River
1WR145	36.06660	33.94651	Houch en Nabi	Industrial discharge	Into Litani River
1WR146	36.08396	33.93810	Houch en Nabi	Industry	Into ditch
1WR154	35.98436	33.84647	Rayyak	Waste water discharge	Into Hala river
1WR155	35.98857	33.84642	Rayyak	Dumpsite	Waste Disposal
1WR157	35.96352	33.84064	Dalhamiye	Waste water discharge	Into Litani River
1WR162	35.97805	33.85488	Ablah	Waste water discharge	Into Litani River
1WR163	35.97944	33.85611	Ablah	Industrial discharge	Tanmiya
1WR164	35.98010	33.85638	Ablah	Industrial discharge	Tanmiya
1WR169	35.94432	33.82151	Dalhamiye	Waste water discharge	Into Litani River
1WR171	35.95435	33.83691	Karak	Waste water discharge	Into Litani River
1WR172	35.91307	33.80082	Zahle	Waste water discharge	Into Litani River
1WR173	35.77760	33.63640	Jib Jannine	Waste water discharge	Into Litani River
1WR211	35.94022	33.81450	Zahle	Industrial discharge	Discharge from poultry slaughterhouse on litani
1WR219	36.04365	33.91360	Haouch El rafqa	Waste water discharge	WW Houch el Rafqa area
1WR228	35.92355	33.79992	Zahle	Industrial discharge	Rock cutting industry, upstream zahle landfill

Appendix C. List of sampled surface water locations

Code	*E (DD)*	*N (DD)*	*Elevation (m)*	*Description*	*Remarks*
2WR001	35.67782	33.57805	1023	Spring in Bab Mareh	Ain el Dib - Next to road, source in mountain, no residential area above or below
2WR002	35.66959	33.56064	1044	Spring in Aitanit	Ain Aitanit - Next to road, source in mountain, water discharges through village, no wastewater effluent
2WR004	35.72154	33.61354	857	Normal Flow point	Bridge in Saghbine above Litani River (River, lake bottle neck before 1WR005)
2WR007	35.69900	33.61156	1019	Spring in Saghbine	Ain el Tayyoun - spring running under village with septic tanks
2WR013	35.71246	33.62872	983	Spring in Ain Zebde	Used for irrigation
2WR014	35.71880	33.63013	985	spring in Khraizat area	Khraizat spring source - below road - behind Hotel Khraizat
2WR016	35.77954	33.63873	853	Normal Flow point	Jib Jannine Bridge - point is after Kamed el Louz wastewater discharge point, and before Jib Jannine wastewater discharge point
2WR021	35.81829	33.67977	870	Normal Flow point	Bridge between Mansoura and Ghazze (location is before Ghazze and Louce wastwater discharge on Litani, and after Ghazze waste disposal site)
2WR024	35.83102	33.72910	863	Joint of Ghzayel with Litani	On the Spot!
2WR028	35.95697	33.74433	863	Chamsine Spring	Point is at the spring source
2WR029	35.94617	33.73266	879	Ghzayel River - Anjar Spring	Behind MoA fisheries
2WR030	35.91208	33.75501	869	Normal Flow point	Bridge over Ghzayyel (or referred to as Dayr Zanoun) between Bar Elias and Anjar
2WR036	35.82637	33.70397	872	Joint on Litani	Earthen canal discharging Ammiq swamp water - (called Nahr el Riyashi), agricultural drainage, and other tributaries fom Tal el Akhdar, and Kab Elias Area
2WR045	35.81223	33.79827	982	Spring in Kabelias	Ras el Ayn - source of Kabelias river
2WR050	35.89281	33.77757	896	Normal Flow point	Bridge over Litani river on Chtaura El Marj Road
2WR051	35.87878	33.76825	888	Normal Flow point	Bridge over Litani river, downstream of junction between combined Chtaura/Berdouni river, and Litani river.

Code	*E (DD)*	*N (DD)*	*Elevation (m)*	*Description*	*Remarks*
2WR052	35.88342	33.77256	886	Joint on Litani	Berdouni/Chtaura combined flow joining Litani river at this spot
2WR053	35.83027	33.80959	936	Normal Flow point	Bridge over Mekse river on Qabelias/Chtaura road
2WR061	35.83412	33.82454	967	Spring in Jdita	Naba'a Jdita
2WR067	35.84347	33.81049	912	Zebdol river	Point on Zebdol river
2WR070	35.85229	33.81179	904	Normal Flow point	Bridge over Chtaura river downstream of 2WR069
2WR075	35.85086	33.82405	892		Chtaura Spring source
2WR080	35.87420	33.78082	870	Normal Flow point	Bridge over combined flow of Chtaura river and Jalala river before Dayr Taanayel area
2WR088	35.87142	33.88750	1237	Berdouni Spring	Spring Source in Qaa el Rim - location is on bridge next to well heads
2WR093	35.88002	33.86970	1096	Normal flow point	Point is near Muntazah Wadi El Rim on Berdouni river downstream of Mimosa factory
2WR100	35.91346	33.83215	922	Normal Flow point	Bridge over Berdouni in Zahle after crossing Zahle - Baalbeck road (downstream of 2WR099)
2WR104	35.90067	33.81928	894	Normal Flow point	Bridge over Berdouni river downstream of 2WR103 close to Electrical Power plants
2WR113	35.92562	33.80120	880	Normal Flow point	Point is upstream of Landfill site on Litani river
2WR114	35.91299	33.79168	882	Normal Flow point	Point is downstream of Landfill site on Litani river
2WR115	35.90401	33.78302	884	Normal Flow point	Point is on Litani river downstream of Landfill site before entering Barelias area
2WR129	35.99945	33.86852	915	Normal Flow point	Bridge over Litani river on road from Temnin Tahta to Baalbeck highway
2WR135	36.02825	33.89141	931	Normal Flow point	Bridge over Litani river behind El Tal, upstream of 2WR134
2WR147	36.06112	33.94371	961	Normal Flow point	Bridge over Litani river downstream of 2WR145 and just upstream of 2WR140
2WR156	35.96375	33.84068	874	Normal Flow point	Bridge over Litani river on Dalhamiye - Karak road
2WR159	35.96480	33.84169	885	Normal Flow point	Joint of Hala river with Litani
2WR166	35.96961	33.84642	918	Normal Flow	Metal bridge over Litani river downstream of Tanmiya

Code	*E (DD)*	*N (DD)*	*Elevation (m)*	*Description*	*Remarks*
				point	
2WR168	35.94492	33.82219	894	Normal Flow point	Dalhamiye Bridge over Litani - downstream is bridge over Litani from Industrial area in Zahle towards Faour, and Upstream is bridge 2WR156 over Litani after Junction with Hala river)
2WR170	35.94967	33.83072	889	Normal Flow point	Bridge over Litani river - upstream of Dalhamiye bridge
2WR178	35.82653	33.77340	880	Normal Flow point	Point is on Hafir river downstream of all Qabelias wastewater discharge (upstream of 2WR176, and downstream of 2WR177)
2WR184	35.69166	33.56626			Qaroun Lake Samples
2WR185	35.69390	33.56591			Qaroun Lake Samples
2WR186	35.69624	33.56537			Qaroun Lake Samples
2WR187	35.68976	33.56046			Qaroun Lake Samples
2WR188	35.69234	33.55992			Qaroun Lake Samples
2WR189	35.69481	33.55957			Qaroun Lake Samples
2WR190	35.69343	33.55363			Qaroun Lake Samples
2WR191	35.69212	33.55487			Qaroun Lake Samples
2WR192	35.68844	33.55449			Qaroun Lake Samples
2WR193	35.69001	33.55037			Qaroun Lake Samples
2WR194	35.69613	33.58995			Qaroun Lake Samples
2WR195	35.69769	33.57125			Qaroun Lake Samples
2WR196	35.69521	33.57172			Qaroun Lake Samples
2WR197	35.69273	33.57212			Qaroun Lake Samples
2WR198	35.69918	33.57722			Qaroun Lake Samples
2WR199	35.69656	33.57764			Qaroun Lake Samples
2WR200	35.69415	33.57803			Qaroun Lake Samples
2WR201	35.69811	33.58348			Qaroun Lake Samples
2WR202	35.69565	33.58387			Qaroun Lake Samples
2WR203	35.70060	33.58302			Qaroun Lake Samples
2WR204	35.77433	33.63647	861		Litani river, Downstream Jib Jannine WW outlet
2WR208	35.86701	33.75748	871		Litany river, downstream 2WR051

Code	*E (DD)*	*N (DD)*	*Elevation (m)*	*Description*	*Remarks*
2WR209	35.83319	33.73334	874		Litany river, upstream ghzayel joint
2WR210	35.82924	33.72416	864		Litany river, downstream ghzayel joint
2WR212	35.93576	33.81039	882		Litani river, downstream 2WR109 and upstream 2WR113
2WR213	35.94418	33.81992	887		Litani river, upstream 2WR211 and downstream 2WR169
2WR214	35.96077	33.83937	901		Litani river, downstream ferzol ww
2WR215	35.97675	33.85397	899		Litani river, downstream ablah WW and tanmiya discharge
2WR216	35.98689	33.86210	907		Litani river, after riyak bridge, before tanmiya
2WR217	35.99633	33.86610	908		Litani river, downstream ww of tamnine tahta and fawqa
2WR218	36.02101	33.88306	921		Litani, downstream bednayel ww
2WR220	36.04078	33.90958	946		Litani river, downstream WW Houch el Rafqa
2WR221	36.04475	33.91732	950		Litani river, upstream WW Houch el Rafqa
2WR223	36.06007	33.94263	967		Litani river, after chmistar ww
2WR225	36.07962	33.96610	990		Litani river, downstream 2WR224
2WR227	35.91526	33.79437	880		Litani river, downstream zahle landfill
2WR229	35.82536	33.70185	864		Litani river after joint with Hafir/Gair combined flow
2WR230	35.82644	33.70582	866		Litani river - before joint with combined flow of Hafir/Gair river
2WR231	35.85281	33.81587	879		Chtaura river, before wastewater - Masabki hotel
2WR233	35.85652	33.80059	890		Chtaura river, upstream of 2WR078
2WR234	35.85818	33.79960	888		Chtaura river, downstream of 2WR078
2WR235	35.90267	33.82097	906		Berdouni river, upstream of 2WR103
2WR236	35.89391	33.80965	885		Berdouni river, downstream of 2WR106, and upstream of 2WR107
2WR237	35.88930	33.80515	882		Berdouni river, downstream of wastewater discharge at 2WR107 near the dumpsite
2WR238	35.89295	33.79575	880		Berdouni river, upstream of 2WR108
2WR239	35.89282	33.79350	879		Berdouni river, downstream of 2WR108
2WR240	35.88301	33.77547	877		Chtaura river before joint with Berdouni
2WR241	35.88531	33.77615	875		Berdouni river before joint with Chtaura
2WR243	35.88531	33.77367	871		Litani river, before joint with combined flow of Berdouni/Chtaura
2WR245	35.90172	33.75859	857		Ghzayyel river, downstream of 2WR118(WW discharge of Barelias are that could

Code	*E (DD)*	*N (DD)*	*Elevation (m)*	*Description*	*Remarks*
					not be sampled since pipe is embedded in flow channel) and upstream of 2WR117
2WR246	35.89173	33.75962	864		Ghzayyel river, downstream of 2WR117 and 2WR118
2WR248	35.83370	33.80388	897		Mekse river, downstream of WW at 2WR055
2WR249	35.85051	33.78548	872		Jdita river, upstream of joint of Mekse and Jdita
2WR252	35.82355	33.79575	927		Qab Elias river, after leaving residential area near LRA station
2WR253	35.81575	33.74556	873		Hafir river, downstream of WW discharge and Sicomo effluent - in Tal Akhdar area (2WR042)
1WR263	35.65771	33.48766		Ain Ez Zarqa Spring	
2WC001	35.70044	33.54608	887	Canal 900	Water Sample - Canal 900
2WC003	35.71463	33.55939	904	Canal 900	Water Sample - Canal 900
2WC004	35.71829	33.56327	909	Canal 900	Water Sample - Canal 900
2WC005	35.72059	33.57319	910	Canal 900	Water Sample - Canal 900
2WC006	35.72498	33.58667	912	Canal 900	Water Sample - Canal 900
2WC007	35.7283	33.59391	912	Canal 900	Water Sample - Canal 900
2WC008	35.73051	33.60265	912	Canal 900	Water Sample - Canal 900
2WC010	35.75111	33.61438	916	Canal 900	Water Sample - Canal 900
2WC011	35.76379	33.61937	916	Canal 900	Water Sample - Canal 900
2WC012	35.77937	33.62663	913	Canal 900	Water Sample - Canal 900
2WC013	35.79242	33.62953	910	Canal 900	Water Sample - Canal 900
2WC014	35.80828	33.62734	909	Canal 900	Water Sample - Canal 900
2WC015	35.72625	33.57464		Canal 900	Main Tank - Qaroun Network
2WC016	35.73473	33.60137		Canal 900	Main Tank - Lala/Baaloul
2WC017	35.7358	33.60435		Canal 900	Irrigation Outlet - Baaloul
2WC018	35.76263	33.62026		Canal 900	Irrigation Outlet - Lala
2WC019	35.80318	33.62616		Canal 900	Main Tank - Jib Jannin/Kamed el Louz
2WC021	35.77784	33.63317		Canal 900	Irrigation Outlet - Jib Jannin
2WC022	35.72403	33.58435		Canal 900	Irrigation Outlet - Qaroun

Appendix D. List of sampled groundwater wells

Code	*E (DD)*	*N (DD)*	*Elevation (m)*	*Village*	*Use*	Description
2kG001	36.07756	33.92009	1010	Sifri	Drinking	Inside an Agricultural area
2kG002	36.07382	33.92456	998	Sifri/AREC	Drinking	Near AREC
2kG003	36.04805	33.92400	961	Housh Ar Rafqa	Drinking &Irrigation	Place known as dao al kamar
2kG004	36.05530	33.93122	968	Haoush An Nabi	Drinking &Irrigation	Along the village main road
2kG005	35.99184	33.86429	915	Rayak	Not certain	Along the village main road
2kG006	35.98105	33.86132	907	Ablah	Drinking	Near the river
2kG007	35.93137	33.82344	897	Zahle	Industrial	Stone Industry
2kG008	35.93487	33.81947	893	Zahle	Industrial	Beton Bekaa
2kG009	35.94758	33.80587	886	Zahle	Drinking &Irrigation	Along the village main road
2kG010	35.91776	33.82101	905	Haoush Al Oumara	Irrigation	Along the village main road
2kG011	35.90642	33.80479	881	Zahle	Drinking	Amreyeh Mosque
2kG013	35.89416	33.82650	897	Ksara	Drinking	Near Ksaara factory
2kG015	35.94747	33.79659	880	Bar Elias	Drinking	Along the village main road
2kG016	35.77193	33.64661	863	Joub Jannine	Drinking &Irrigation	1 km from landfill
2kG017	35.79990	33.63671	878	Joub Jannine	Drinking &Industrial	Along the village main road
2kG019	35.78334	33.63065	887	Joub Jannine	Drinking	Along the village main road
2kG020	35.79674	33.63057	899	Joub Jannine	Drinking &Irrigation	place known as Oushaysh
2kG021	35.71918	33.57243	907	Qaraoun	Industrial	Stone Industry
2kG022	35.70412	33.55269	872	Qaraoun	Industrial	Gas Station
2kG025	35.74793	33.58894	1118	Baaloul	Drinking	Along the village main road
2kG026	35.73071	33.58289	963	Baaloul	Drinking	Owned by Baladiyah
2kG029	35.91474	33.73409	891	Majdel Anjar	Drinking &Irrigation	Along the village main road
2kG030	35.90138	33.72290	884	Majdel Anjar	Industrial &Irrigation	Close to Sugar Factory
2kG032	35.83616	33.68617	869	Ghazze	Drinking &Irrigation	Along the village main road
2kG034	35.82273	33.66163	860	Ghazze	Irrigation	Along the village main road
2kG040	35.86752	33.67792	896	Dakoue	Drinking &Irrigation	Known as AL Rashidiyeh
2kG044	35.75659	33.65670	916	Kafraiya	Irrigation	Near Chateau Kefraya
2kG045	35.83778	33.80799	892	Meksi	Drinking	Known as Ain Al Sakhira-direction of gas factory
2kG046	35.83120	33.80239	909	Qabb Elias	Irrigation	Known as Hay Al Kuroum
2kG049	35.78341	33.71357	871	Housh Aammiq	Irrigation	Owned by Skaf family(place=AL Naoura)
2kG050	35.76014	33.64393	869	Khirbet Qanafar	Irrigation	Inside an Agricultural area
2kG051	35.71386	33.63703	1057	Khirbet Qanafar	Drinking	Along the village main road
2kG053	35.77862	33.66232	878	Tall Znoub	Drinking	Inside an Agricultural area
2kG054	35.95381	33.84845	892	Fourzol	Irrigation	Along the village main road
2kG055	35.95678	33.84069	889	Fourzol	Irrigation	Along the village main road
2kG056	35.98797	33.86633	911	Nabi Aila	Irrigation	Along the village main road
2kG057	36.00709	33.85297	932	Rayak	Drinking	Along the village main road

Code	*E (DD)*	*N (DD)*	*Elevation (m)*	*Village*	*Use*	Description
2kG058	36.02967	33.87918	949	Housh El-Ghanam	Drinking &Irrigation	Along the village main road
2kG060	36.06812	33.91301	1005	Saraain et Tahta	Industrial	Well owned by Al Mousawi Foundation
2kG061	36.04334	33.94002	990	Housh Bay	Drinking	Along the village main road
2kG062	36.04855	33.95184	995	Housh Bay	Drinking	Along the village main road
2kG063	36.03778	33.96560	1090	Chmistar	Drinking	Along the village main road
2kG064	36.04679	33.95591	1012	Chmistar	Drinking &Irrigation	Along the village main road
2kG065	36.06395	33.95901	1006	Taraiya	Drinking	Along the village main road
2kG069	36.06807	33.98636	1019	Wadi Messerta	Irrigation	Along the village main road
2kG070	36.08908	33.97424	995	Hizzine	Drinking &Irrigation	Along the village main road
2kG071	36.10621	33.96174	1011	Hizzine(near Britel)	Drinking	Along the village main road
2kG072	36.12113	34.00339	1022	Houch Barada	Drinking	Along the village main road
2kG073	36.11052	34.00576	1012	Houch Barada	Drinking &Irrigation	Along the village main road
2kG074	35.90503	33.83354	918	Haoush Al Oumara	Drinking	Along the village main road
2kG075	36.02546	33.90393	936	Bednayel	Irrigation	Along the village main road
2kG076	35.71783	33.56647	883	Qaraoun	Drinking	Along the village main road
2kG077	35.88230	33.78640	870	Taanayel	Drinking &Irrigation	Along the village main road
2kG078	35.84594	33.70868	876	Housh Al harimeh	Irrigation	Along the village main road
2kG079	35.81344	33.77665	879	Qabb Elias	Drinking	Along the village main road
2kG081	35.75543	33.60749	983	Lala	Industrial &Irrigation	Along the village main road
2kG082	35.76980	33.62584	917	Lala	Drinking	Along the village main road
2kG083	35.89319	33.72398	821	Majdel Anjar	Drinking &Irrigation	Along the village main road
2kG084	35.85589	33.66681	884	Tal Al Zaaazih	Drinking &Irrigation	Along the village main road
2kG085	35.77935	33.68399	895	Aana	Drinking &Irrigation	Along the village main road

Appendix E. List of soil samples location

Sample code	*GPS coordinates*		*Description*
	N	*E*	
1WO001	33.57672	035.71552	Qaraoun area, irrigated from Canal 900 (scheme 1, Qaraoun)
1WO002	33.58104	035.71507	Qaraoun area, irrigated from Canal 900 (scheme 1, Qaraoun)
1WO003	33.58431	035.71619	Qaraoun area, irrigated last year from GW. well. The year before from Canal 900 (scheme 1, Qaraoun), wheat cultivated
1WO004	33.57158	035.71420	Qaraoun area, irrigated from GW well only
1WO005	33.59161	035.72623	Qaraoun area, upstream Canal 900, irrigated last year from Canal 900 by direct pumping, previous years fallow
1WO006	33.60408	035.73769	Lala area, irrigated from Canal 900 (scheme 2, Lala)
1WO007	33.60931	035.74274	Lala area, irrigated from Canal 900 (scheme 2, Lala)
1WO008	33.61759	035.74764	Lala area, irrigated from Canal 900 (scheme 2, Lala)
1WO009	33.62271	035.75706	Lala area, not irrigated, almond cultivated
1WO011	33.63854	035.78046	Joub Jannine area, irrigated from Canal 900 (scheme 3, Joub Jannine-Kamed el Laouz)
1WO012	33.65019	035.79826	Joub Jannine area, irrigated from Canal 900 (scheme 3, Joub Jannine-Kamed el Laouz)
1WO013	33.63784	035.80101	Joub Jannine area, irrigated from Canal 900 (scheme 3, Joub Janine-Kamed el Laouz)
1WO014	33.62484	035.82811	Kamed el Laouz area, irrigated from GW well only
1WO015	33.62817	035.81718	Kamed el Laouz area, irrigated from Canal 900 (scheme 3, Jib Janine-Kamed el Laouz)
1WO016	34.02248	036.09513	Saaide area, irrigated from Yammouneh canal and groundwater well
1WO017	34.01690	036.09780	Saaide area, irrigated from Yammouneh canal and groundwater well
1WO018	34.00936	036.09583	Saaide area, irrigated from Yammouneh canal and groundwater well
1WO019	33.99851	036.09602	Saaide area, irrigated from Yammouneh canal and groundwater well
2WO021	33.62333	35.75669	Lala area, irrigated from Canal 900 (scheme 2, Lala)
2WO022	34.02414	36.08825	Yammouneh/GW
2WO023	33.5811	35.7205	Qaraoun area, irrigated from Canal 900 (scheme 1, Qaraoun)
2WO024	33.57219	35.71841	Qaraoun area, irrigated from Canal 900 (scheme 1, Qaraoun)
2WO025	33.58714	35.72849	Qaraoun area, irrigated from Canal 900 (scheme 1, Qaraoun)
2WO026	33.6159	35.75042	Lala area, irrigated from Canal 900 (scheme 2, Lala)
2WO027	33.61949	35.76139	Lala area, irrigated from Canal 900 (scheme 2, Lala)
2WO028	33.6321	35.77934	Canal 900
2WO029	33.6432	35.80444	Canal 900/GW
2WO030	33.64489	35.8075	Canal 900
2WO031	33.59507	35.72839	Rainfed
2WO032	33.59896	35.72162	Canal 900

Appendix F. List of crop samples location

Sample Code	*Coordinates*		*Crop Type*	*Description*
	N	*E*		
2WV01	33.63854	35.78046	Sugar beet	Joub Jannine area, irrigated from Canal 900 (scheme 3, Joub Jannine-Kamed el Laouz)
2WV02	33.62333	35.75669	Potato	Lala area, irrigated from Canal 900 (scheme 2, Lala)
2WV03	33.58431	35.71619	Potato	Qaraoun area, irrigated from Canal 900 (scheme 1, Qaraoun)
2WV04	33.56954	35.71683	Peach	Qaraoun area, irrigated from Canal 900 (scheme 1, Qaraoun)
2WV05	33.57678	35.71556	Wild cucumber	Qaraoun area, rainfed irrigation
2WV06	33.58307	35.71658	Potato	Qaraoun area, irrigated from Canal 900 (scheme 1, Qaraoun)
2WV07	33.58481	35.71804	Tomato	Qaraoun area, irrigated from Canal 900 (scheme 1, Qaraoun)
2WV08	33.60901	35.74238	Beans	Lala area, irrigated from a groundwater well
2WV09	33.60923	35.7422	Tomato	Lala area, irrigated from a groundwater well
2WV10	33.6156	35.75033	Sugar beet	Lala area, irrigated from Canal 900 (scheme 2, Lala)
2WV11	33.62188	35.75966	Potato	Lala area, irrigated from Canal 900 (scheme 2, Lala)
2WV12	33.63188	35.77919	Beans	Joub Jannine area, irrigated from Canal 900 (scheme 3, Joub Janine-Kamed el Laouz)
2WV13	33.64314	35.80413	Squash	Joub Jannine area, irrigated from Canal 900 (scheme 3, Joub Janine-Kamed el Laouz) and from a groundwater well
2WV14			Tomato	Joub Jannine area, irrigated from Canal 900 (scheme 3, Joub Janine-Kamed el Laouz) and from a groundwater well
2WV15			Onion	Joub Jannine area, irrigated from Canal 900 (scheme 3, Joub Janine-Kamed el Laouz)

Appendix G. Guidelines for sample collection[1]

1. Guidelines

The following general guidelines can be applied to the collection of water samples (to be analyzed for physical or chemical variables) from rivers and streams, lakes or reservoirs and groundwater:

- Before collecting any sample, make sure that you are at the right place. This can be determined by the description of the station, from the position of landmarks and, in lakes, by checking the depth. If samples must be taken from a boat, a sampling station may be marked by placing a buoy at the desired location; otherwise it is necessary to identify the sampling station by the intersection of lines between landmarks on the shore.
- Before collecting well water sample, re-inspect the well for damage, missing parts, and evidence of tampering.
- Do not include large, non-homogeneous pieces of detritus, such as leaves, in the sample. Avoid touching and disturbing the bottom of a water body when taking a depth sample, because this will cause particles to become suspended.
- Sampling depth is measured from the water surface to the middle of the sampler.
- Samples taken to describe the vertical profile should be taken in a sequence that starts at the surface and finishes at the bottom. When taking the sample at the maximum depth it is important to ensure that the bottom of the sampler is at least 1 m above the bottom.
- Do not lower a depth sampler too rapidly. Let it remain at the required depth for about 15 seconds before releasing the messenger (or whatever other device closes the sampler). The lowering rope should be vertical at the time of sampling. In flowing water, however, this will not be possible and the additional lowering necessary to reach the required depth should be calculated.
- A bottle that is to be used for transport or storage of the sample should be rinsed three times with portions of the sample before being filled. This does not apply, however, if the storage/transport bottle already contains a preservative chemical.
- The temperature of the sample should be measured and recorded immediately after the sample is taken.
- At any time that the sample bottles are not closed, their tops must be kept in a clean place.
- A small air space should be left in the sample bottle to allow the sample to be mixed before analysis.
- **Make sure you collected an adequate volume for subsequent laboratory analysis.**
- Collect a quality control sample for the whole sampling episode, preferably during the first couple of days, whereby one duplicate sample will be collected.
- All measurements taken in the field must be recorded in the field notebook before leaving the sampling station.
- All supporting information should be recorded in the field notebook before leaving the sampling station. Such conditions as the ambient air temperature, the weather, the presence of dead fish floating in the water or of oil slicks, growth of algae, or any unusual sights or smells should be noted, no matter how trivial they may seem at the time. These notes and observations will be of great help when interpreting analytical results.
- Samples should be transferred to sample bottles immediately after collection if they are to be transported. If analysis is to be carried out in the field, it should be started as soon as possible.

Samples for bacteriological analysis

Most of the guidelines for sampling for physical and chemical analyses apply equally to the collection of samples for bacteriological analyses. Additional considerations are:

- **Samples for bacteriological analyses should be taken in a sterile sampling cup and should be obtained before samples for other analyses.**

[1] Adapted from UNEP/WHO, 1996. Water Quality Monitoring - A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes.

- **Care must be exercised to prevent contamination of the inside of the sampling cup and sampling containers by touching with the fingers or any non-sterile tools or other objects.**
- **Bottles in which samples for bacteriological analyses are to be collected (or transported) should be reserved exclusively for that purpose.**

2. <u>Procedures</u>

Sampling from a tap or pump outlet

1. Clean the tap. Remove any attachments that may cause splashing from the tap. These attachments are a frequent source of contamination that may influence the perceived quality of the water supply. Use a clean cloth to wipe the outlet and to remove any dirt.
2. **Open the tap. Turn on the tap to maximum flow and let the water run for 1-2 minutes. Turn off the tap. For wells, make sure a minimum of three water column volumes has been purged**
3. ***Note:* Some people omit the next two steps and take the samples at this stage, in which case the tap should not be adjusted or turned off, but left to run at maximum flow.**
4. **Sterilize the tap for 1 minute with a flame (from a gas burner, cigarette lighter or an alcohol-soaked cotton wool swab)-if practical.**
5. **Open the tap before sampling. Carefully turn on the tap and allow water to flow at medium rate for 1 - 2 minutes. Do not adjust the flow after it has been set.**
6. Fill the bottle. Carefully remove the cap and protective cover from the bottle, taking care to prevent entry of dust that may contaminate the sample. Hold the bottle immediately under the water jet to fill it. A small air space should be left to allow mixing before analysis. Replace the bottle cap.

Sampling water from a water-course or reservoir

Open the sterilized bottle as described in step 5 above.

1. Hold the bottle near its bottom and submerge it to a depth of about 20 cm, with the mouth facing slightly downwards. If there is a current, the bottle mouth should face towards the current. Turn the bottle upright to fill it. Replace the bottle cap.

Appendix H. Lab analysis results

Appendix H1. Results of physico-chemical and microbiological analysis of surface water samples collected between June and July, 2005

Sample ID	*Date of sampling*	*Matrix*	*pH*	*Temp °C*	*DO (mg/L)*	*TDS (mg/L)*	*NH_3 (mg/L)*	*NO_3 (mg/L)*	*PO_4 (mg/L)*	*SO_4 (mg/L)*	*BOD (mg/L)*	*COD (mg/L)*	*FC (CFU/ 100 ml)*	*TC (CFU/ 100 ml)*
2WR001	1-Jul-05	Spring	7.08	16.2	5.56	159	0.01	10.7	0.05	33	2	2	0	36
2WR002	1-Jul-05	Spring	7.07	17.1	6.19	122	0.01	7.2	0.01	7	2	2	0	2
2WR004	1-Jul-05	River	7.30	24.0	5.04	223	0.25	6	1.27	18	6	14	400	3400
2WR007	1-Jul-05	Spring	6.82	17.7	5.65	184	0.01	13.6	0.1	22	2	2	12	151
2WR013	1-Jul-05	Spring	7.05	17.7	6.01	186	0.01	11.7	0.02	27	2	2	1	15
2WR014	1-Jul-05	Spring	6.95	18.1	5.32	184	0.02	10.4	0.14	7	2	2	14	31
2WR016	22-Jun-05	River	6.95	24.0	2.61	188	0.11	9.2	1.41	7	2	9	0	220
2WR021	22-Jun-05	River	7.03	23.3	3.39	191	1.95	10	1.07	7	5.8	7	300	7000
2WR024	22-Jun-05	River	7.18	23.6	3.79	175.5	0.725	14.6	0.735	12	2.85	3	380	1450
2WR027	24-Jun-05	River	7.22	23.4	3.74	191	1.1	10	0.92	17	3.2	10	500	6700
2WR028	24-Jun-05	Spring	7.03	18.5	6.12	174	0.02	13.2	0.06	14	2	2	31	52
2WR029	24-Jun-05	Spring	7.06	18.7	6.05	167	0.02	11.7	0.03	16	2	3	12	34
2WR030	24-Jun-05	Spring	7.10	21.2	6.41	175	0.04	12.4	0.1	16	2	4	2800	6900
2WR036	22-Jun-05	River	7.20	23.48	3.76	183.25	0.91	12.30	0.83	14.50	3.03	6.50	440.00	4075.00
2WR045	27-Jun-05	Spring	7.04	16.8	5.48	124	0.07	5.1	0.02	19	2	2	16	79
2WR050	20-Jun-05	River	6.88	21.7	3.14	368	14	18.5	4.4	39	20	23	100000	100000
2WR051	20-Jun-05	River	7.03	21.4	3.61	261	9.875	6.5	2.715	37	6.8	12	150000	150000
2WR052	20-Jun-05	River	7.06	21.1	6.20	205	4.5	7.2	1.11	33	4.2	4.5	35000	35000
2WR053	27-Jun-05	River	7.30	17.0	5.05	233	0.48	8.3	0.98	27	2	2	16000	160000
2WR061	27-Jun-05	Spring	6.57	15.6	5.63	122	0.01	7.6	0.05	16	2	2	13	200
2WR067	27-Jun-05	River	6.85	18.6	2.65	199	9.4	6.5	2.09	20	22	46	177000	250000
2WR070	24-Jun-05	River	7.07	17.3	3.58	175	1.4	9.7	0.85	7	20	29	60000	60000
2WR075	24-Jun-05	Spring	6.82	17.5	5.63	141	0.1	8.4	0.12	7	2	2	2700	13900
2WR080	24-Jun-05	River	7.18	18.1	5.57	166	0.42	6.9	0.25	13	6	9	4100	12300
2WR088	23-Jun-05	Spring	6.90	11.7	6.92	88.2	0.04	4.5	0.07	7	2	2	3	73
2WR093	23-Jun-05	River	7.20	13.1	6.53	96.5	0.15	4.9	0.1	7	2	2	23000	107000
2WR100	23-Jun-05	River	7.40	14.1	6.52	98	0.14	6.2	0.11	7	2	2	20000	20000

Sample ID	*Date of sampling*	*Matrix*	*pH*	*Temp °C*	*DO (mg/L)*	*TDS (mg/L)*	*NH_3 (mg/L)*	*NO_3 (mg/L)*	*PO_4 (mg/L)*	*SO_4 (mg/L)*	*BOD (mg/L)*	*COD (mg/L)*	*FC (CFU/ 100 ml)*	*TC (CFU/ 100 ml)*
2WR104	23-Jun-05	River	7.30	17.2	6.06	139	5.5	8.9	2.08	7	32	58	120000	1500000
2WR113	20-Jun-05	River	7.02	20.0	3.75	282	12	21.9	3.2	23	8.8	10	700000	700000
2WR114	20-Jun-05	River	6.90	20.3	3.33	280	6.25	24.7	2.6	27	5.2	9	750000	750000
2WR115	20-Jun-05	River	6.89	20.7	2.79	303	13	20.9	2.4	28	2	2	700000	700000
2WR129	15-Jun-05	River	6.93	24.2	1.89	700	13	14.4	5	42	10	23	600000	600000
2WR135	15-Jun-05	River	7.28	21.3	7.13	373	3.4	44.2	1	8	2	2	18400	23200
2WR147	15-Jun-05	River	7.30	19.5	2.90	515	42	23.9	17	7	80	411	85000	120000
2WR156	16-Jun-05	River	7.10	20.9	1.15	628	31	12.7	63	42	123	234	600000	600000
2WR159	16-Jun-05	River	7.26	23.1	1.19	706	80	22.4	197	23	227	398	1000000	1000000
2WR166	16-Jun-05	River	7.13	21.5	0.95	654	38	15.9	61	31	177	347	700000	700000
2WR168	16-Jun-05	River	7.19	23.3	1.12	592	30	13.4	52	40	78	146	800000	800000
2WR170	16-Jun-05	River	7.20	24.6	0.81	660	35	10.5	64	7	73	121	93000	400000
2WR178	27-Jun-05	River	7.18	23.8	0.43	390	80	45.1	27.4	44	521	838	1500000	1500000
2WR204	22-Jun-05	River	7.13	24.4	4.11	195	0.39	10.5	1.55	7	3.5	7	47000	104000
2WR208	20-Jun-05	River	7.28	23.5	4.48	262	13	5.3	4	24	6	8	500000	500000
2WR209	22-Jun-05	River	6.84	20.4	2.94	183	6.25	3.7	3.9	18	8	21	22000	78000
2WR210	22-Jun-05	River	7.13	21.8	4.90	187	2.05	9.3	1.35	7	5	7	1680	17000
2WR212	20-Jun-05	River	7.14	20.5	0.87	494	64	14.2	12.2	34	184	348	122000	800000
2WR213	16-Jun-05	River	7.19	23.4		555	29	7.8	46	7	63	108	800000	800000
2WR214	16-Jun-05	River	7.07	21.8	0.64	664	32	7.4	49	8	122	220	800000	800000
2WR215	16-Jun-05	River	7.10	18.5	1.40	620	28	5.3	41	9	103	206	450000	450000
2WR216	16-Jun-05	River	7.23	18.5	2.15	603	14	4.9	28	24	30	62	450000	450000
2WR217	15-Jun-05	River	7.08	24.0	1.40	444	18.5	11.5	8	4	40	48	284000	500000
2WR218	15-Jun-05	River	6.90	22.7	1.54	666	21.5	13.3	6	48	231	390	400000	400000
2WR220	15-Jun-05	River	7.17	20.3	3.24	372	9.5	50.6	11	21	10	11	500000	500000
2WR221	15-Jun-05	River	6.98	20.3	6.56	329	0.66	62	10	33	2	2	3100	7600
2WR223	15-Jun-05	River	7.25	19.6	1.32	537	44	15.1	30	7	76	215	500000	500000
2WR225	15-Jun-05	River	6.88	19.4	0.45	427	22	7.8	32	7	57.2	86	600000	600000
2WR227	20-Jun-05	River	6.92	18.7	3.22	275	4.5	26.8	3.4	26	10	12	248000	300000

Sample ID	Date of sampling	Matrix	pH	Temp °C	DO (mg/L)	TDS (mg/L)	NH_3 (mg/L)	NO_3 (mg/L)	PO_4 (mg/L)	SO_4 (mg/L)	BOD (mg/L)	COD (mg/L)	FC (CFU/ 100 ml)	TC (CFU/ 100 ml)
2WR229	22-Jun-05	River	7.05	21.6	4.30	185	1	7.5	0.91	7	3.8	5	400	12000
2WR230	22-Jun-05	River	7.11	22.0	4.68	181	1.65	12.7	1.33	7	4.1	6	1550	30000
2WR231	24-Jun-05	River	7.14	15.9	5.77	146	0.06	7.1	0.11	7	2	7	90000	90000
2WR233	24-Jun-05	River	7.04	17.8	4.03	147	1.1	5.8	0.34	12	5	10	90800	90800
2WR234	24-Jun-05	River	7.00	18.7	3.68	170	1.2	6.1	0.03	12	16.4	18	70000	70000
2WR235	23-Jun-05	River	7.68	17.0	6.75	97	0.07	4	0.06	7	2	2	28000	102000
2WR236	23-Jun-05	River	7.44	18.5	7.83	142	4.6	10.7	1.18	7	8.9	9	16000	1000000
2WR237	23-Jun-05	River	7.19	19.8	4.46	185	11.5	16.1	38	7	46	58	282000	1000000
2WR238	23-Jun-05	River	7.06	20.1	4.37	179	3.25	14.1	0.81	19	10.5	67	16000	158000
2WR239	23-Jun-05	River	7.18	21.1	4.11	191	5.8	12.7	1.74	20	10	15	23000	1000000
2WR240	24-Jun-05	River	7.32	19.1	6.47	161	0.19	4.3	0.23	14	3.1	4	13400	20700
2WR241	24-Jun-05	River	6.97	19.6	2.67	179	6.25	9	1.93	22	7.2	12	80000	80000
2WR243	20-Jun-05	River	7.13	23.0	3.23	310.5	16	10.55	4	35	35.15	45	530000	530000
2WR245	24-Jun-05	River	7.11	21.6	4.28	192	1.6	12.1	0.43	18	4	4	60000	60000
2WR246	24-Jun-05	River	7.06	22.0	3.46	190	1.7	11.6	0.57	17	7	7	120000	120000
2WR248	27-Jun-05	River	7.27	20.4	0.97	499	120	44.9	32	44	454	714	1500000	1500000
2WR249	27-Jun-05	River	7.01	18.2	1.90	236	15	3	4	28	14.6	24	69000	400000
2WR252	27-Jun-05	River	7.35	17.3	6.12	123	0.05	7.6	0.03	15	2	2	1000	17000
2WR253	27-Jun-05	River	6.90	24.5	0.66	593	0.24	10.6	0.17	225	624	950	7000	20000
2WR263	1-Jul-05	Spring	7.12	18.2	5.96	192	0.36	24.5	0.39	23	2	2	13	13

Appendix H2. Results of physico-chemical and microbiological analysis of samples from industrial and domestic wastewater effluents collected between June and July, 2005

Sample ID	*Date of sampling*	*Matrix*	*pH*	*Temp*	*DO*	*TDS*	*NH_3*	*NO_3*	*PO_4*	*SO_4*	*BOD*	*COD*	*FC (CFU/ 100 ml)*	*TC (CFU/ 100 ml)*
				°C	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*		
2WF089	23-Jun-05	IWW	7.10	24.7	5.43	235	0.01	1.8	0.04	28	110	195	15800	2900
2WR042	27-Jun-05	DWW	6.77	22.3	0.84	560	0.18	6.6	0.13	215	653	970	200000	11000
2WR044	27-Jun-05	IWW	7.01	28.6	4.15	633	0.01	6.3	0.03	400	713	950	123000	0
2WR055	27-Jun-05	DWW	7.48	23.3	0.34	625	200	52.1	49.5	39	924	1272	1200000	1200000
2WR056	27-Jun-05	DWW	7.36	21.4	2.40	263	28	11.5	6.1	70	111	154	500000	500000
2WR069(a)	24-Jun-05	DWW	7.20	21.7	4.02	790	44	28.1	25.6	26	936	1934	2200000	2200000
2WR069(b)	24-Jun-05	DWW	7.06	19.3	4.00	231	1.8	6.1	0.67	26	11.3	36	400000	28000
2WR103	23-Jun-05	DWW	7.30	23.0	1.21	455	78	20.7	32	9	237	488	1000000	1000000
2WR107	23-Jun-05	DWW	7.18	22.7	0.16	566	50	66.9	49	10	683	1264	1000000	1000000
2WR108	23-Jun-05	DWW	7.02	25.0	1.46	341	55	18.8	24	8	246	257	500000	500000
2WR109	20-Jun-05	DWW	7.17	21.1	1.07	486	54	28.9	13.8	33	296	360	600000	600000
2WR112	20-Jun-05	DWW	7.00	20.5	1.68	426	43	21.6	10.2	44	102	214	800000	800000
2WR128	16-Jun-05	DWW	7.82	20.0	2.18	894	235	38.8	123	30	274	638	600000	600000
2WR130	15-Jun-05	DWW	7.04	23.3	2.20	443	29	18.7	18	8	248	450	800000	800000
2WR132	15-Jun-05	DWW	6.43	22.5	1.22	3340	36	0.5	30	7	1413	2480	1000000	1000000
2WR134	15-Jun-05	DWW	7.14	22.5	0.00	610	120	50.9	40	7	473	1128	1000000	1000000
2WR145	15-Jun-05	Manure	7.63	22.0	3.86	1610	225	12.7	59	7	260	1253	500000	500000
2WR157	16-Jun-05	DWW	7.02	20.7	1.43	523	36	20.6	99	34	228	360	1000000	1000000
2WR162	16-Jun-05	DWW	7.37	21.2	0.03	868	160	55.1	142	38	325	799	1200000	1200000
2WR171	16-Jun-05	DWW	6.58	26.0	0.65	1130	115	58.4	109	12	1953	2956	700000	700000
2WR173	22-Jun-05	DWW	7.06	25.5	3.04	343	47	28.1	8.4	16	263	525	1300000	1300000
2WR211	20-Jun-05	Poultry WW	7.01	18.9	3.91	442	14	60.9	4.1	40	72	81	700000	60000
2WR219	15-Jun-05	DWW	7.32	21.6	1.27	700	95	48.9	34	11	546	1038	1000000	1000000

Appendix H3. Results of physico-chemical and microbiological analysis of lake water samples collected during June, 2005

Sample ID	*Depth*	*Date of sampling*	*Matrix*	*pH*	*Temp °C*	*DO (mg/L)*	*TDS (mg/L)*	*NH_3 (mg/L)*	*NO_3 (mg/L)*	*PO_4 (mg/L)*	*SO_4 (mg/L)*	*BOD (mg/L)*	*COD (mg/L)*	*FC (CFU/ 100 ml)*	*TC (CFU/ 100 ml)*
2WR184(a)	2/3 d	29-Jun-05	Lake	6.5	16.5	1.9	170	0.92	20.3	0.38	29	3.4	4	0	0
2WR184(b)	1/3 d	29-Jun-05	Lake	6.9	19.4	2.2	155	0.34	26.7	0.1	30	2	10	0	0
2WR185(a)	2/3 d	29-Jun-05	Lake	7.1	17	1.9	166	0.54	24.5	0.32	29	2.3	7	0	0
2WR185(b)	1/3 d	29-Jun-05	Lake	7.3	22	6.3	129	0.48	31.2	0.03	30	3.1	13	0	0
2WR186(a)	2/3 d	29-Jun-05	Lake	6.9	19.1	2.5	152	0.52	24	0.21	30	2	3	53	156
2WR186(b)	1/3 d	29-Jun-05	Lake	7.5	22.4	7.7	120	0.64	23.6	0.06	30	3.3	13	0	0
2WR187(a)	2/3 d	29-Jun-05	Lake	6.9	20.5	2.2	165	0.52	24.9	0.25	33	3.7	10	450	450
2WR187(b)	1/3 d	29-Jun-05	Lake	7.3	22.4	6.7	128	0.46	24.3	0.01	29	3.2	11	0	0
2WR188(a)	2/3 d	29-Jun-05	Lake	7	19.3	2.2	164	0.1	18.6	0.18	29	2	9	0	0
2WR188(b)	1/3 d	29-Jun-05	Lake	7.2	23	6.2	126	0.08	18.2	0.07	30	3.9	11	0	0
2WR189(a)	2/3 d	29-Jun-05	Lake	7	19.8	2	158	0.1	19.8	0.23	31	2	6	0	0
2WR189(b)	1/3 d	29-Jun-05	Lake	7.2	22.7	6.2	130	0.04	23.8	0.17	31	3	11	0	0
2WR190(a)	2/3 d	29-Jun-05	Lake	7	21.4	2.1	157	0.12	24.1	0.15	28	2.4	25	0	0
2WR190(b)	1/3 d	29-Jun-05	Lake	6.9	20.5	1.9	162	0.02	17.2	0.3	33	2.8	65	0	0
2WR191(a)	2/3 d	29-Jun-05	Lake	6.8	19.4	1.3	175	0.66	17.2	0.47	31	2.7	3	0	2
2WR191(b)	1/3 d	29-Jun-05	Lake	7	20.7	2.2	159	0.1	20.2	0.23	32	2	8	0	0
2WR192(a)	2/3 d	29-Jun-05	Lake	6.9	20.3	1.6	162	0.22	22.6	0.33	30	2.3	3	0	2
2WR192(b)	1/3 d	29-Jun-05	Lake	7	23.6	2.9	138	0.16	20	0.02	30	2.4	7	0	0
2WR193(a)	2/3 d	30-Jun-05	Lake	6.5	17.4	2.1	196	0.46	21.7	0.38	30	2.2	8	0	0
2WR193(b)	1/3 d	30-Jun-05	Lake	6.6	18.9	2	186	0.07	23.1	0.1	30	2	3	0	0
2WR194	mid	30-Jun-05	Lake	7.3	24.8	4.9	153	0.34	16.5	0.03	28	2.7	5	1	2
2WR195	mid	30-Jun-05	Lake	7.1	17.8	2.7	188	0.26	23.6	0.26	28	4	5	0	2
2WR196	mid	30-Jun-05	Lake	7	19.2	2.5	185	0.18	20.4	0.16	27	2	7	1	21
2WR197	mid	30-Jun-05	Lake	7	19.4	2.5	189	0.12	22.5	0.17	27	2	9	0	1
2WR198	mid	30-Jun-05	Lake	7	22.5	4.9	157	0.13	16.1	0.01	31	2.4	8	1	33
2WR199	mid	30-Jun-05	Lake	6.9	22.7	4	163	0.15	19.6	0.03	25	2.5	8	0	9
2WR200	mid	30-Jun-05	Lake	7.1	20.7	2	184	0.12	23.5	0.17	27	2	6	0	2

Sample ID	*Depth*	*Date of sampling*	*Matrix*	*pH*	*Temp °C*	*DO (mg/L)*	*TDS (mg/L)*	*NH_3 (mg/L)*	*NO_3 (mg/L)*	*PO_4 (mg/L)*	*SO_4 (mg/L)*	*BOD (mg/L)*	*COD (mg/L)*	*FC (CFU/ 100 ml)*	*TC (CFU/ 100 ml)*
2WR201	mid	30-Jun-05	Lake	7.1	22.3	2.8	172	0.3	19.6	0.17	27	2.3	7	0	2
2WR202	mid	30-Jun-05	Lake	7.1	21.6	3.1	175	0.2	22	0.14	29	2	5	0	0
2WR203	mid	30-Jun-05	Lake	7.2	24.5	4.9	149	0.1	20.3	0.01	26	2.5	10	0	1

Appendix H4. Results of physico-chemical and microbiological analysis of samples from Canal 900

Sample ID	*Date of sampling*	*Matrix*	*pH*	*Temp °C*	*DO (mg/L)*	*TDS (mg/L)*	*NH_3 (mg/L)*	*NO_3 (mg/L)*	*PO_4 (mg/L)*	*SO_4 (mg/L)*	*BOD (mg/L)*	*COD (mg/L)*	*FC (CFU/ 100 ml)*	*TC (CFU/ 100 ml)*
2WC001	6-Jul-05	Canal	6.81	16.4	2.12	208	0.86	20.3	0.54	33	2	2	0	400
2WC003	6-Jul-05	Canal	6.70	16.3	2.55	202	0.78	21.8	0.4	32	2	2	0	36
2WC004	6-Jul-05	Canal	6.77	15.8	2.32	208	0.96	24.4	0.42	31	2	2	14	88
2WC005	6-Jul-05	Canal	6.85	16.5	2.23	205	0.74	20.5	0.4	30	2	4	0	106
2WC006	6-Jul-05	Canal	6.92	18.3	3.54	202	0.46	23.2	0.38	32	2	5	700	1400
2WC007	6-Jul-05	Canal	7.15	20.0	5.57	193	0.39	21.7	0.23	31	2	5	1	32
2WC008	6-Jul-05	Canal	7.05	19.5	4.91	203	0.7	21.1	0.24	30	2	2	5	18
2WC010	6-Jul-05	Canal	7.05	21.1	5.87	189	0.53	21.1	0.21	32	2	7	0	33
2WC011	6-Jul-05	Canal	7.24	22.1	7.64	184	0.55	20.8	0.13	32	2	2	700	1400
2WC012	6-Jul-05	Canal	7.34	22.4	7.76	182	0.32	16.7	0.11	30	2	5	700	1400
2WC013	6-Jul-05	Canal	7.46	23.1	7.25	180	0.13	18.6	0.08	29	2	7	1	70
2WC014	6-Jul-05	Canal	7.36	25.7	6.76	148	0.25	14.9	0.01	30	2	15	15	64
2WC015	6-Jul-05	Canal	6.85	16.3	3.18	202	0.56	21.9	0.37	31	2	10	5	86
2WC016	6-Jul-05	Canal	7.08	20.7	5.85	190	0.35	21.7	0.2	27	2	10	264	560
2WC017	6-Jul-05	Canal	7.06	22.2	5.35	197	1.04	11.2	0.35	29	2	9	1200	2400
2WC018	6-Jul-05	Canal	7.13	21.1	5.61	186	0.11	19.5	0.29	30	2	10	1100	2200
2WC019	6-Jul-05	Canal	7.35	23.2	5.92	182	0.3	15.4	0.02	30	2	8	38	314
2WC020	6-Jul-05	Canal	7.32	24.4	5.84	179	0.01	18.9	0.04	30	2	12	6	42
2WC021	6-Jul-05	Canal	7.28	25.0	4.52	181	0.07	17.2	0.08	30	2	5	71	272
2WC022	6-Jul-05	Canal	6.98	22.5	2.00	202	0.16	24	0.42	30	2	2	0	74

Samples collected from locations where copper sulfate was added as part of the ongoing algae control program

Sample ID	*Date of sampling*	*Matrix*	*pH*	*Temp °C*	*DO (mg/L)*	*TDS (mg/L)*	*NH_3 (mg/L)*	*NO_3 (mg/L)*	*PO_4 (mg/L)*	*Total Hardness (mg/L)*	*Conductivity (mg/L)*	*Salinity (mg/L)*
HeadC900	13-Jul-05	Canal	7.11	20.9	2.14	235	0.82	16.8	0.5	212	490	0.2
K1	13-Jul-05	Canal	7.07	21.4	2.26	234	0.76	19.5	0.44	203	491	0.2
K2-A	13-Jul-05	Canal	7.22	23.7	4.16	227	0.52	13.6	0.25	199	477	0.2
JJ-A	13-Jul-05	Canal	7.42	27.3	4.17	208	0.16	17.7	0.1	177	436	0.2

Appendix H5. Results of physico-chemical and microbiological analysis of groundwater samples collected during June, 2005

Sample ID	*Date received*	*Matrix*	*pH*	*Temp °C*	*DO (mg/L)*	*TDS (mg/L)*	*NH_3 (mg/L)*	*NO_3 (mg/L)*	*PO_4 (mg/L)*	*SO_4 (mg/L)*	*BOD (mg/L)*	*COD (mg/L)*	*FC (CFU/ 100 ml)*	*TC (CFU/ 100 ml)*
2KG001	14-Jun-05	GW	6.96	28.8	-	-	-	63.8	0.1	8	-	-	10	0
2KG002	14-Jun-05	GW	6.71	33.3	-	-	-	59.9	0.12	8	-	-	0	0
2KG003	24-Jun-05	GW	6.80	20.2	-	-	-	47.9	0.07	35	-	-	111	111
2KG004	24-Jun-05	GW	7.07	19.8	-	-	-	23.2	0.04	14	-	-	30	0
2KG005	14-Jun-05	GW	6.77	29.8	-	-	-	24.1	0.12	70	-	-	114	13
2KG006	16-Jun-05	GW	6.95	18.8	-	-	-	19	0.33	14	-	-	12	0
2KG007	16-Jun-05	GW	6.73	21.6	-	-	-	40.6	0.22	49	-	-	400	2
2KG008	23-Jun-05	GW	7.03	24.1	-	-	-	35.9	0.05	45	-	-	16	0
2KG009	23-Jun-05	GW	6.75	19.2	-	-	-	92.6	0.09	140	-	-	68	4
2KG010	23-Jun-05	GW	6.90	18.8	-	-	-	43.4	0.08	7	-	-	0	0
2KG011	23-Jun-05	GW	6.98	19.4	-	-	-	35.6	0.08	7	-	-	0	0
2KG013	21-Jun-05	GW	6.71	23.2	-	-	-	20.1	0.13	21	-	-	89	23
2KG015	21-Jun-05	GW	6.54	19.9	-	-	-	45.6	0.08	195	-	-	142	94
2KG016	17-Jun-05	GW	6.88	21.3	-	-	-	62.7	0.02	27	-	-	1	0
2KG017	17-Jun-05	GW	6.79	20.7	-	-	-	85.7	0.1	26	-	-	20	0
2KG019	22-Jun-05	GW	6.99	21.9	-	-	-	35.1	0.13	7	-	-	33	0
2KG020	17-Jun-05	GW	6.98	21.2	-	-	-	42.3	0.05	7	-	-	1	0
2KG021	20-Jun-05	GW	7.10	20.4	-	-	-	29.7	0.16	17	-	-	50	0
2KG022	20-Jun-05	GW	6.56	18.4	-	-	-	20.9	0.18	28	-	-	19	0
2KG025	20-Jun-05	GW	7.08	23.6	-	-	-	26.4	0.09	7	-	-	0	0
2KG026	22-Jun-05	GW	7.03	21.4	-	-	-	8.4	0.13	7	-	-	0	0
2KG029	21-Jun-05	GW	7.08	24.2	-	-	-	43.8	0.14	21	-	-	400	1
2KG030	21-Jun-05	GW	7.10	21.7	-	-	-	38.3	0.11	27	-	-	70	28
2KG032	17-Jun-05	GW	6.79	25.2	-	-	-	48.3	0.01	205	-	-	5	5
2KG034	24-Jun-05	GW	6.98	23.8	-	-	-	48.8	0.15	18	-	-	12	1
2KG040	24-Jun-05	GW	7.20	22.0	-	-	-	27.6	0.16	15	-	-	15	0
2KG044	20-Jun-05	GW	6.96	19.3	-	-	-	73.1	0.11	10	-	-	48	0
2KG045	28-Jun-05	GW	6.85	19.7	-	-	-	38.3	0.08	10	-	-	13	1

Sample ID	*Date received*	*Matrix*	*pH*	*Temp °C*	*DO (mg/L)*	*TDS (mg/L)*	*NH_3 (mg/L)*	*NO_3 (mg/L)*	*PO_4 (mg/L)*	*SO_4 (mg/L)*	*BOD (mg/L)*	*COD (mg/L)*	*FC (CFU/ 100 ml)*	*TC (CFU/ 100 ml)*
2KG046	28-Jun-05	GW	6.79	22.7	-	-	-	14.9	0.02	61	-	-	13	0
2KG049	27-Jun-05	GW	7.07	21.2	-	-	-	29.4	0.02	10	-	-	49	12
2KG050	27-Jun-05	GW	7.06	19.2	-	-	-	61.2	0.08	28	-	-	12	1
2KG051	27-Jun-05	GW	6.85	19.9	-	-	-	12.4	0.02	26	-	-	26	3
2KG053	20-Jun-05	GW	6.78	22.0	-	-	-	107.8	0.88	114	-	-	0	0
2KG054	16-Jun-05	GW	6.73	19.1	-	-	-	64.9	0.21	84	-	-	9	0
2KG055	16-Jun-05	GW	6.62	21.2	-	-	-	109.7	11.7	112	-	-	17	0
2KG056	14-Jun-05	GW	7.07	31.0	-	-	-	17.3	0.13	7	-	-	11	0
2KG057	16-Jun-05	GW	6.76	21.0	-	-	-	73.8	0.15	31	-	-	2	0
2KG058	14-Jun-05	GW	6.75	23.7	-	-	-	86.1	0.07	22	-	-	2	0
2KG060	14-Jun-05	GW	7.04	29.7	-	-	-	160.6	0.12	15	-	-	1	1
2KG061	15-Jun-05	GW	7.22	23.0	-	-	-	28.5	0.1	7	-	-	14	2
2KG062	15-Jun-05	GW	7.15	20.3	-	-	-	11.1	0.13	7	-	-	18	2
2KG063	15-Jun-05	GW	7.05	20.9	-	-	-	9.4	0.32	35	-	-	2	0
2KG064	15-Jun-05	GW	7.07	20.1	-	-	-	22.6	0.17	7	-	-	0	0
2KG065	24-Jun-05	GW	6.84	20.4	-	-	-	36.9	0.14	7	-	-	0	0
2KG069	13-Jun-05	GW	7.09	25.0	-	-	-	71	0.03	8	-	-	150	149
2KG070	13-Jun-05	GW	6.86	24.0	-	-	-	140.3	0.01	10	-	-	18	2
2KG071	13-Jun-05	GW	7.03	21.0	-	-	-	56	0.02	7	-	-	0	0
2KG072	13-Jun-05	GW	7.06	22.0	-	-	-	170.8	0.02	17	-	-	59	0
2KG073	13-Jun-05	GW	7.01	20.3	-	-	-	136.6	0.04	7	-	-	16	0
2KG074	23-Jun-05	GW	6.56	20.5	-	-	-	31.6	0.01	7	-	-	12	0
2KG075	15-Jun-05	GW	6.65	20.4	-	-	-	75.5	0.18	7	-	-	4	0
2KG076	22-Jun-05	GW	6.67	19.8	-	-	-	18.3	0.3	7	-	-	20	0
2KG077	17-Jun-05	GW	6.89	30.6	-	-	-	2.8	0.05	44	-	-	100	5
2KG078	17-Jun-05	GW	7.03	24.7	-	-	-	3	0.01	60	-	-	0	0
2KG079	28-Jun-05	GW	7.02	22.5	-	-	-	31.7	0.04	7	-	-	0	0
2KG081	22-Jun-05	GW	6.94	21.9	-	-	-	14	0.31	7	-	-	10	0
2KG082	20-Jun-05	GW	6.78	20.5	-	-	-	18.5	0.04	31	-	-	73	1

Sample ID	*Date received*	*Matrix*	*pH*	*Temp °C*	*DO (mg/L)*	*TDS (mg/L)*	*NH_3 (mg/L)*	*NO_3 (mg/L)*	*PO_4 (mg/L)*	*SO_4 (mg/L)*	*BOD (mg/L)*	*COD (mg/L)*	*FC (CFU/ 100 ml)*	*TC (CFU/ 100 ml)*
2KG083	21-Jun-05	GW	6.69	20.2	-	-	-	37.5	0.1	23	-	-	0	0
2KG084	24-Jun-05	GW	6.81	21.0	-	-	-	34.4	0.08	13	-	-	10	0
2KG085	27-Jun-05	GW	7.04	21.1	-	-	-	29	0.06	12	-	-	244	2

Appendix H6. Results of analysis on heavy metals in water samples

Sample ID	*Date of sampling*	*Matrix*	*Copper (µg/L)*	*Zinc (mg/L)*	*Nickel (µg/L)*	*Lead (µg/L)*	*Chromium (µg/L)*	*Cadmium (µg/L)*
2KG013	21-June-05	GW	4.2	<0.1	<1.0	<1.0	1.2	<0.1
2KG015	21-June-05	GW	1.2	0.109	2.0	<1.0	<1.0	<0.1
2KG083	21-June-05	GW	1.8	<0.1	<1.0	<1.0	<1.0	<0.1
2KG019	22-June-05	GW	1.7	0.552	<1.0	<1.0	<1.0	<0.1
2KG026	22-June-05	GW	<1.0	<0.1	<1.0	<1.0	1.1	<0.1
2KG081	22-June-05	GW	<1.0	<0.1	<1.0	<1.0	1.5	<0.1
2KG008	23-June-05	GW	2.9	<0.1	<1.0	<1.0	<1.0	<0.1
2KG003	24-June-05	GW	<1.0	<0.1	<1.0	<1.0	1.0	<0.1
2KG004	24-June-05	GW	2.0	<0.1	<1.0	<1.0	6.6	<0.1
2KG079	28-June-05	GW	1.4	<0.1	<1.0	<1.0	<1.0	<0.1
2WR184(b)	29-June-05	Lake	NR	NR	NR	<1.0	<1.0	<0.1
2WR185(b)	29-June-05	Lake	NR	NR	NR	<1.0	<1.0	<0.1
2WR186(b)	29-June-05	Lake	NR	NR	NR	<1.0	<1.0	<0.1
2WR187(b)	29-June-05	Lake	NR	NR	NR	<1.0	<1.0	<0.1
2WR188(b)	29-June-05	Lake	NR	NR	NR	<1.0	<1.0	<0.1
2WR189(b)	29-June-05	Lake	NR	NR	NR	<1.0	<1.0	<0.1
2WR190(b)	29-June-05	Lake	NR	NR	NR	<1.0	<1.0	<0.1
2WR191(b)	29-June-05	Lake	NR	NR	NR	<1.0	<1.0	<0.1
2WR192(b)	29-June-05	Lake	NR	NR	NR	<1.0	<1.0	<0.1
2WR193(b)	30-June-05	Lake	NR	NR	NR	<1.0	<1.0	<0.1
2WR194	30-June-05	Lake	NR	NR	NR	<1.0	<1.0	<0.1
2WR195	30-June-05	Lake	NR	NR	NR	<1.0	<1.0	<0.1
2WR196	30-June-05	Lake	NR	NR	NR	<1.0	<1.0	<0.1
2WR197	30-June-05	Lake	NR	NR	NR	<1.0	<1.0	<0.1
2WR198	30-June-05	Lake	NR	NR	NR	<1.0	<1.0	<0.1
2WR199	30-June-05	Lake	NR	NR	NR	<1.0	<1.0	<0.1
2WR200	30-June-05	Lake	NR	NR	NR	<1.0	<1.0	<0.1
2WR201	30-June-05	Lake	NR	NR	NR	<1.0	<1.0	<0.1
2WR202	30-June-05	Lake	NR	NR	NR	<1.0	<1.0	<0.1
2WR203	30-June-05	Lake	NR	NR	NR	<1.0	<1.0	<0.1

NR: Not requested

Appendix H7. Results of analysis on pesticides on groundwater samples

Organophosphorus pesticide profile

Sample ID	*Triethyl phosphorothioate*	*Thionazin (Zinophos)*	*Sulfotep*	*Phorate*	*Methyl parathion*	*Parathion*	*Famphur*
2KG003	ND	ND	ND	ND	ND	ND	ND
2KG004	ND	ND	ND	ND	ND	ND	ND
2KG008	ND	ND	ND	ND	ND	ND	ND
2KG013	ND	ND	ND	ND	ND	ND	ND
2KG015	ND	ND	ND	ND	ND	ND	ND
2KG019	ND	ND	ND	ND	ND	ND	ND
2KG026	ND	ND	ND	ND	ND	ND	ND
2KG079	ND	ND	ND	ND	ND	ND	ND
2KG081	ND	ND	ND	ND	ND	ND	ND
2KG083	ND	ND	ND	ND	ND	ND	ND

ND: Not detected

Organochlorine pesticide profile

Sample ID	*Alpha-BHC*	*Gamma-BHC (Lindane)*	*Beta-BHC*	*Heptachlor*	*Delta-BHC*	*Aldrin*	*Heptachlor Epoxide*	*Endosulfan I*	*4,4'DDE*	*Dieldrin*	*Endrin*	*4,4'DDD*	*Endosulfan II*	*4,4'DDT*	*Endrin Aldehyde*	*Endosulfan Sulfa*
2KG003	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2KG004	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2KG008	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2KG013	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2KG015	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2KG019	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2KG026	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2KG079	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2KG081	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2KG083	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND: Not detected.

Appendix H8. Results of analysis on heavy metals in soil samples

Code	*Matrix*	*Chromium (mg/Kg)*	*Copper (mg/Kg)*	*Cadmium (mg/Kg)*
2WO001	Soil	195.79	52.66	2.40
2WO002	Soil	150.73	40.08	1.94
2WO003	Soil	377.20	6.68	3.30
2WO004	Soil	371.25	38.91	7.46
2WO005	Soil	214.49	59.73	3.16
2WO006	Soil	131.48	2.96	1.17
2WO007	Soil	55.56	31.82	0.69
2WO008	Soil	33.41	8.69	1.05
2WO009	Soil	56.24	34.44	1.41
2WO011	Soil	46.06	26.06	1.25
2WO012	Soil	325.00	7.19	4.54
2WO013	Soil	259.92	4.98	2.67
2WO014	Soil	81.16	36.92	3.90
2WO015	Soil	71.07	40.13	2.64
2WO016	Soil	57.68	16.25	0.16
2WO017	Soil	60.80	15.74	0.10
2WO018	Soil	91.71	27.70	1.39
2WO019	Soil	101.36	25.26	1.00
2WO021	Soil	11.35	30.55	0.78
2WO022	Soil	123.91	28.56	0.86
2WO023	Soil	129.03	44.50	1.22
2WO024	Soil	138.40	61.98	2.31
2WO025	Soil	114.10	33.07	0.87
2WO026	Soil	365.91	87.96	6.19
2WO027	Soil	269.22	64.48	2.33
2WO028	Soil	222.60	57.67	3.81
2WO029	Soil	184.91	51.98	4.09
2WO030	Soil	150.96	29.78	2.19
2WO031	Soil	229.30	90.70	14.10
2WO032	Soil	234.30	75.80	12.78

Appendix H9. Results of analysis on heavy metals in crop samples

Code	*Matrix*	*Chromium (mg/Kg)*	*Copper (mg/Kg)*	*Cadmium (mg/Kg)*
2WV01	Sugar beet	15.044	1.691	0.058
2WV02	Potato	17.629	2.100	0.060
2WV03	Potato	13.537	2.727	0.063
2WV04	Peach	2.262	0.806	0.097
2WV05	Wild cucumber	3.410	0.815	0.079
2WV06	Potato	1.606	1.257	0.981
2WV07	Tomato	1.868	0.496	0.291
2WV08	Beans	5.446	0.687	0.701
2WV09	Tomato	0.112	0.475	0.717
2WV10	Sugar beet	0.159	1.011	0.191
2WV11	Potato	0.271	0.949	0.486
2WV12	Beans	0.175	0.705	0.039
2WV13	Squash	0.158	0.402	0.061
2WV14	Tomato	0.310	0.703	0.061
2WV15	Onion	0.241	0.442	0.227

Appendix H10. Results of analysis on fish samples

Fish	*Chromium (mg/Kg)*	*Cadmium (mg/Kg)*	*Copper (mg/Kg)*
1	0.253	0.340	3.0
2	0.237	0.174	2.193
3	0.527	2.653	1.72
4	0.347	8.131	1.523
5	0.140	0.198	1.60
6	0.399	0.198	1.645
7	NR*	NR	NR
8	NR	NR	NR
9	NR	NR	NR
Detection limit	0.002	0.125	-

* NR: not reported, quality control check failed